ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

Department of Civil Engineering

ASSESSMENT OF URBAN WATER SUPPLY AND DEMAND:

The Case of Sebeta Town, Ethiopia

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A thesis submitted to the school of graduate studies of Addis Ababa Science and Technology University in partial fulfillment of the requirements for the Degree of Master of Science in Hydraulic Engineering.

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Declaration

I here by declare that the work in the thesis entitled **"Assessment of Urban Water Supply and Demand: the Case of Sebeta Town, "** was composed by myself under the supervision of Dr. Brook Abate in the College of Architecture and Civil Engineering, Addis Ababa Science & Technology University in the year 2018. The information derived from literature has been duly acknowledged in the text and a list of references provided.

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Approval/ Certificate Page

This is to certify that the thesis prepared by Mr. Tariku Negewo entitled “Assessment of Urban Water Supply and Demand: the Case of Sebeta Town” and submitted in fulfillment of the requirements for the Degree of Master of Science in Hydraulic Engineering complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Urban water supply and demand challenges are the widespread problems in most of the developing countries such as Ethiopia. Water demand has been increasing significantly in most cities due to population growth and other factors. As a result, the town water utilities are struggling to provide customers with adequate and reliable water supply service. Water distribution systems are designed to fulfill all requirements of potable water needed for decades. Initial system designs frequently consider any anticipated changes likely to happen. However, as time elapsed they slowly begin to fail to satisfy customers' requirements; both in quantity quality. The wonder is to identify factors which bring those changes and propose viable solutions to improve the situation. To this effect modeling water distribution network system is very helpful. In this study, Sebeta water supply and demand was assessed. Water CAD software was used as tool to model water distribution system. The modeling effort included hydraulic modeling. Simulation results for maximum and minimum pressures were used as base to evaluate the hydraulic performance. Modeling results showed violation of maximum and minimum pressure requirements. Household interviews and questionnaires were made to understand customers' satisfaction towards the water supply service in terms of water availability, adequacy of the water, tariff affordability and water consumption. Water quality tests were conducted to compare the water quality with the WHO standards. From this study, water quality test results showed that, some parameters departed from WHO water quality guidelines. It is recommended that the water utility develop a strategy and work hard on the indicated system deficiencies to improve the water supply and demand and provide customers with good quality service.

KEY WORDS*: Water supply, Water quality, Water CAD Modeling, Hydraulic performance, Sebeta, Ethiopia.*

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Abbreviations and acronyms

CSA	Central Statistical Agency
DCI	Ductile Cast Iron
EPA	Environmental Protection Agency
EPS	Extended Period Simulation
GI	Galvanized Steel
GPS	Global Position System
HDPE	Highly Density Polyethylene
MoWR	Ministry of Water Resources
STWSSO	Sebeta Town Water Supply System Office
UNDP	United Nation Development Program
UN-HABITAT	United Nations Human Settlements Program
UNICEF	United Nations Children's Fund
USEPA	United State Environmental Protection Agency
UPVC	Un plastic Polyvinylchloride
UNESCO	United Nations, Scientific and Cultural Organization
WHO	World Health Organization
WSDP	Water Sector Development Program

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Water is one of the basic necessities for the existence of living things in general and human beings in particular. For any municipal town, efficient water supply and sanitation is an indispensable service. Without meeting the water supply and demand of the town, enhancement of developmental activities and improving health condition of communities is impossible.

Despite the efforts of numerous international commitments, a significant number of populations are lacking access to safe water and sanitation. In developing countries 1.1 billion people have inadequate access to water, and 2.6 billion people lack basic sanitation ((UNDP, 2006)). Due to the lack of access to safe water and basic sanitation at least 1.6 million children under the age of five die every year (WHO/UNICEF, 2006).

Ethiopia like any other developing countries has many constraints to make potable water easily accessible. Only 38% of total population and 26% of rural population have access to safe and clean water (WHO and UNICEF, 2010). To improve access to safe clean water, the government of Ethiopia has prepared a Water and Sanitation Policy document as an integral part of the country's water management policy.

Provision of safe and adequate water supply service is necessary component for sustainable development. The estimated water supply service level of Ethiopia in terms of coverage, quantity, quality and reliability is very low. The water and sanitation coverage in Ethiopia is one of the lowest in Africa.

Water CAD was adjusted to allow for modeling pressure dependent demands, for dealing with low pressure and dry pipe situations. A configurable tool was developed for incorporating roof tanks in to the water supply analysis and for better formulation and schematization of the system hydraulics.

Hydraulic analysis of flows and pressures in a distribution system has been a standard form of engineering analysis since its development by Hardy Cross in 1936. Water distribution system computer models have been in use since the middle 1960s and have evolved in to sophisticated, user friendly tools that are capable of simulating large distribution systems (Walisk et al., 2001).

In order to facilitate the examination of required pipe sizes, the standard water CAD model was use. As in other developing towns, a rapid population growth and high rural-urban migration poses many social and environmental challenges for the town of Sebeta of which inadequacy of water supply and sanitation services are crucial. The situation of insufficient and unsafe water supply, especially for communities using unprotected water sources like river/spring and rain water harvesting open ponds in rural areas and poor urban areas which have no access to a yard or community tap, is believed to result in poor environmental conditions and an ever-present risk of epidemics, which in turn bring about a formidable threat to health and productivity of the dwellers. There is, thus, an urgent need for improved water supply and sanitation systems.

Sebeta is one of the towns in Ethiopia with a high rate of population growth and a rapid sectorial and industrial development to which infrastructural developments are not in proportion with. The high development and expansion of the town is mainly attributed to the expansion of real estates, commercial areas, industrial zones and housing projects either by government and private sectors. The rapid extension of the urban areas in different parts of the town necessitates optimization and upgrading of the water supply and other important infrastructures in order to provide the required services and to protect the health and environment of the targeted population.

A well performing urban water supply should provide water supply for human being and livestock consumption, for industrial and other uses in terms of coverage, quantity, reliability and acceptable quality taking the existing and future realities of the town in to the consideration. This research paper will focus on investigating the problems in relation to the availability, production, distribution mechanisms, and the consumption of water in Sebeta and recommend solutions for improving the water supply service.

1.2 Statement of the Problem

Some local studies were conducted in relation to urban water supply problems in Ethiopia. Among them is by Chala, (2011). His findings revealed that the shortage of water supply, high cost of piped water connection, and frequnt interruption were the major problems in Ambo town water supply service.

Another study which was conducted by Asefa Delesho (2006). His study was mainly focused on the cause of water problems in Assosa Town. His finding indicates that the water supply of Asosa town could not satisfy the consumption of the people due to increase in the number of the population of the town and weak capacity of water supply service of the town. Thus his study focuses on the factors rather than the other issues to be assessed.

Generally the studies conducted at national level indicated that the supply of water varies from place to place based on residence and consumption was low compared with other countries. The existing water supply systms to the Sebeta town did not satisfy the water requirement in quality and quantity for these tremendously increasing populations of the town. However, there was no previous study done in Sebeta town with this regard. Thus, as filling the gap of other researches, this study was actually intended to assess the availabilty, distribution mechanisms, production, the needs and consumptions of water in Sebeta town. It also assessed the root causes and the major challenges of water supply and demand in the town. In addition, there are villages in the town which are out of the reach of distribution pipes and villages with distribution pipes, but unavailability of water in the pipes.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this study is to assess the supply and demand in the provision of adequate water supply in Sebeta Town.

1.3.2 Specific Objectives

1. To assess the status of the existing water supply and demand in the town.
2. To project the demand for 20 years and suggest possible sources of water.

3. To evaluate the hydraulic performance of the distribution network using WATER CAD software.
4. To assess the availability, distribution, quality, water tariff and consumption of water of the town.

1.4 Research Questions

The objective of the study was achieved by answering the following questions:

1. How is the status of coverage of existing water supply of the town?
2. Are the availabilty, distribution and consumption of water found at satisfactory level in the town?
3. Does the water supply service office of the town have affordable water tariff to the residents?
4. Is the distribution system hydraulically efficient?

1.5 Significance of the Study

- Studying the coverage of urban water supply service in Sebeta town helps to identify the pressing problems in service delivery.
- Thus, the findings of the study are significant for the municipality of the town for designing more effective method of water supply by narrowing the information gap between supply and demand

1.6 Thesis Outline

This thesis comprises five chapters, which are organized as follows:

- Chapter One: General baground, general objective, specific objectives, the research questions, statement of the problem.
- Chapter Two: Literature review related to urban water supply and demand
- Chapter Three: Materials and Methods
- Chapter Four: Results and discussion
- Chapter Five: Conclusion and recommendation

CHAPTER TWO

2. REVIEW OF LITERATURE

2.1 Urban water supply

In the world over 800 million people use unimproved drinking water sources in 2010, and in 2015 estimates about 672 million people will still use unimproved drinking water resources in the world. At the beginning of 2000, about 1.1billion people in the world were without access to improved water supply in most parts of the world (Bandari and Grant, 2007).

Delivering effective urban water service needs to be supported by appropriate and good working condition of the water supply system. Urban water supply systems typically includes water collection and storage facilities at source sites, water transport via pipelines from source sites to water treatment facilities; then from water treatment to the distribution systems. Problems in these components importantly affect the urban water service (Muna, 2006).

Fresh water will be a critical limiting resource for many regions in the near future. About one-third of the world's population lives in countries that are experiencing water stress. In Asia, where water has always been regarded as an abundant resource, per capita availability declined by 40-60 percent in 1990's. Projections suggest that most Asian countries will have severe water problems by the year 2025. Most of African countries historically have been water poor.

The problem is that the populationis growing rapidly putting more pressure on our water supply.

UNICEF (2010) reported that in the world 884 million people use unimproved drinking water sources in 2010, and in 2015 estimates about 672 million people are still using unimproved drinking water sources.

Drinking water or potable water is defined as that having acceptable quality interms of its physical, chemical, biological and acceptabilty parameters so that it can be safely used for drinking and cooking (WHO, 2004). World Health Organization (WHO) defines drinking water to be safe as long as it does not cause the population any significant health risks over a life time of consumption and effort should be made to maintain drinking water quality at the highest possible level.

Domestic water use takes the form of drinking, washing, cooking and sanitation, while productive water uses include those for agriculture, beer brewing, brick making, etc. Safe drinking water matched with improved sanitation contributes to the overall well being of people; it has significant bearing on infant mortality rate, longetivity and productivity. However, the mojority of the world's population in both rural and urban settlements does not have access to safe drinking water. Not only their poor access to readly accessible drinking water, even when water is available in these small towns there are risks of contamination due to several factors like in appropriate waste disposal and lack of water supply infrastructure such as pipe line for water Mengistu, (2008).

To have efficient water supply scheme, we require permanent source of water. The capacity of the source should be such as to meet all requirements of the people. The best available source should be selected for meeting the demand.

2.2 Challenges in urban water supply

In provision of adequate clean water and sanitation facilities to urban dwellers, the world faces many challenges, which are related to capacity of the nations, (i.e. technological know how and institutional), inadequate finance, rapid urbanization and declining of global water resource.

2.2.1 Lack of capacity

According to Wallace et al., (2008), capacity is a flexible concept and encompasses the puplic sector, academia; community based organizations and the private sectors, and ranges from the individual to institutions to society as a whole. Capacity can be described in terms of the human, technological, infrastructural, institutional and managerial resources required at all levels from the individual through to national governance. Not only does capacity have to be built within each of these levels, but it has to be intitutionalized and local communities need to be empowerd to use it effectively. Additionally, capacity building incorporates the following:

- The capacity to engage, educate and train; including community awareness building , adult training and formal education; so as to provide sufficient numbers of component human resources to develop and apply enabling systems within the local environment.

- The capacity to measure and understand aquatic systems through monitoring, applied research, technology development and forecasting, so that reliable data are used for analysis and decision making.
- The capacity to develop policies and programs and to legislate, regulate and achieve compliance through effective govermental, non governmental and private sector institutions and through efficient enforcement and community acceptance, particularly for rural areas.
- The capacity to identify and provide appropriate and affordable water technologies, infrastructure services and products through sustainned research, investment and management.

2.2.1.1 Technological capacity

Innovative technologies are essential to overcome barriers to water and sanitation service provision. Technological capacity includes the the development and application of new technologies, the techinical skills needed to effectively construct, operate and manage a technical solution; the translation of information regarding technologies to promote informed decision-making when implementing a techinical solution; the availability and accessibility of spare parts. However, technology providers need a better understanding of local conditions and policies.

2.2.1.2 Institutional capacity

There is a need for institutions that bring together many disciplines, such as the natural sciences, public health, engineering and the social sciences. Integration and interaction between institutions and different sectors of the population, at decision-making, executive and participative levels is required to plan and execute actions in a coordinated way.

2.2.2 Inadequate financing

Historically, water and sanitation has suffered from severe under financing. This results from inadequate internal financial capacity in the poor countries to achieve water and sanitation goals; poor political decisions for allocation of development and; an overall reduction over time in development aid; and the limited cost recovery potential in poverty stricken regions (Wallace et al, 2008).

In addition, poor targeting of aid and a multiplicity of actors and structures compound the financial shortfall. Prioritization of spending plays a key role, with many developing countries investing only a small fraction of many into water compared with military spending. To this end, the Camdessus Panel and others have urged tha corruption, managerial capacity, sustainable cost recovery and legal and contractual aspects of safe water and sanitation management within developing countries be addressed.

2.2.3 Population growth and urbanization

Population growth and rapid urbanization will create a severe scarcity of water as well as tremendous impact on the natural environment. According to UNDP, (2006), in less developed countries, urban population will grow from 1.9 billion in 2000 to 3.9 billion in 2030, averaging 2.3% per year.

Besides having less or not invested in urban infrastructure, Africa is urbanizing faster than any other region. Between 1990 and 2025, the total urban population is expected to grow from 300 to 700 million; and by 2020, it is expected that over 50% of the population in African countries will reside in urban areas. According to the 1994 Ethiopia population census report showed, the total urban population was 7,323,122 (13.7%) of the total population), after ten years (i.e. 2004) the total urban population increased to 17,588,735 (32.89%) and by the year 2015 urban population is going to increase by 22,925,177 (32.26%) Ethiopia Statistical Authority (1994, 2004 and 2015 projection).

2.2.4 Increasing global water scarcity

(UN-HABITAT, 2006)stated that, not only is the numbrs of these requiring better water supplies very large, water itself is becoming scarcer. The number of people living in water-stressed and water scarce over the world is estimated to increase approximately six fold from 1995 to 2025 to reach 2.8 billion.

2.3 Water Consumption in the World

Safe drinking water implies that water is largely free from impurities and microorganisms that frequently causes disease or death. Unsafe drinking water signficantly limits human progress close to half of all people in developing countries suffer from health problems caused by water and sanitation deficits at any given time. To address this burden, the world health organization outlines corrective measures, such as providing access to sufficient quantities of safe water, providing facilities for disposal of sanitary waste, and introducing sound hygiene behaivors (Lall, 2008).

A study conducted in San Julian, El Salvador South America showed that, most of the population (96%) has access to the municipal water system; every HH connection is metered and service is provid ed 24 hours per day. Similar study conducted in two rural of Nicaragua showed that, water supply coverage in the area is 35%. Another case study conducted in Marinilla, North west Colombia indicated that water supply coverage were reaching 99% of the population with all metered connection and provided service of 24 hours a day. A study conducted in Honduras, Latin America since 2004 indicated that, 79% of the people have access to drinking water summarised by (Dessalegn, 2008).

The cascade of ensuring benefits from government investment in water and sanitation is so powerful that it can even be labeled as preventive medicine, with analogies drawn to immunizations. In the coming cascades, water is thus expected to acquire an increasingly important position on the global agenda. Even today, water-related human morbidity and mortality, which results from widely divergent levels of both water quality and quantity, is already widespread, and almost 80% of the global population faces exposure to high threat levels of water insecurity. The impacts of water shortages are particularly acute in the developing world, where rising populations and climate change are expected to cause severe water shortages for one-third of the population in this century (Legese et al., 2006).

2.4 Water Problems in Ethiopia

According to (Demeke, 2009), the geograhpical location of Ethiopia and its endowment with favorable climate provides a relatively higher amount of rainfall in the region. Much of the water, however, flows across the borders being carried away by the trans-boundary Rivers to the neighboring countries. Rushing streams from the Ethiopian highlands from tributaries of famouse Blue Nile, Tekeze, Awash, Omo, Wabeshebele and Baro Akobo rivers which folw across borders to neighboring countries.

In addition to this approximately 7.5 million Ethiopians in Rift Valley area suffer from problems related to high fluoride levels. Nearly 80% of children are affected by dental fluorosis.

Generally, simiral to many African countries, parts of Ethiopia face water shortages, poor sanitation, and lack of access to clean water sources. In addition to this because of the absence of clean water supply the people are exposed to various water born diseases. Not only illness, many people spend their time when collecting water. Thus the issue of clean water supply is not only a matter of satisfying basic needs, it is also an issue of health care.

2.5 Water Policies and Regulatios of Ethiopia

The Federal Ministry of Water Resources in Ethiopia is in charge of setting national policies for the water supply sector. Regional Water Bureaus and wereda water desks are responsible for investment planning and managing town and city water supply systems. The city administration is responsible for appointing a water board chair and other members and approving investments.

The water resources management policy is based on the constitution of the Federal Democratic Republic of Ethiopia. Government Macro Economic and Social policies and development strategies as well as objectives accepted by the Federal Democratic Republic of Ethiopia and the principles of water resources development objectives that would enhance the socio-economic development of the peoples of Ethiopia, furthermore, in consideration of the inclusion of all felt needs and mutual interests of all the peoples of Ethiopia, the policy was discussed in depth and enriched at the growth roots level with representative participants from all regional status up to Wereda level and relevant bureaus (MoWR, 2011).

In similar way, (Yewondwossen, 2012) also indicated that the policy is believed to provide and impetus for the development of water supply for human and animal consumption. It focuses on increasing the coverage, quantity, reliability and acceptable quality, taking the existing and future realities of the country into consideration. Upon implimentation, the policy is expected to achieve the objective of the Ethiopian people to attain adequate, reliable and clean water service that meets the water user’s demand.

The policy of supplying free water to any group expect for emergency, leads in practice to an unfair situation. Since, there are no enough funds to provide such free services, the rural and urban poor are the first to suffer. A better and much more equitable way would be to collect water charges from consumers and then improve and expand the system. Accordingly, the policy envisages supplying improved potable water service for urban areas with tariff structures that are set based on full cost recovery and self reliance (WoWR, 2011).

Tariff regulations ensure that tariff structures are site-specific and determined according to local circumstances. It also ensure that rural tariff settings are based on the objective of recovering operation and maintenance costs while urban tariff structures are based on the bases of full cost recovery. Besides this, it ensures that tariff structures in water supply systems are based on equitable and practical guidelines and criteria. It also establishes a 'Social Tariff' that enables poor communities to cover operation and maintence costs. Additionally, it establishes progressive tariff rates, in urban water supplies, tied to consumption rates.

2.6 The pricing of water services

From the view point of efficiency, a decreasing tariff scheme might seem preferable, while an increasing one would be more effective in moderating water use. On the other hand, a decreasing tariff could promote overuse, since additional units eventually become marginally cheaper, while it is not clear that the marginal cost of supply decreases for large users. Increasing block tariffs might also adversely affect vulnerable groups, such as users who, for health reasons, need to use great amounts of water.

Water demand fluctuates with the seasons of the year (due to weather effects), the day of the week, or the hour of the day, so a seasonal or peak price tariff may be used to promote conservation and efficiency.

2.7 Estimation of water supply and demand

Water demand is often considered to be equal with the water consumption term, but demand depends on many interlinked factors and features. Even though, theoretically, both terms add up to an equal amount, in practice, there are several differentces between these two terms. (Trifunovic, 2008) identified the water consumption to be the quantity of water that is directly utilized by the various categories of consumers. On the other hand, water demand depends on several factors such as: climatic conditions, size and type of settlement, different standards of living, water supply quantities, pressure along the distribution system, supply regime (intermittent or continuous), water costs and tariff structure, quality of water, extent of industrial and commercial activities, existing sanitation/sewerage, availabilty of private water supply, environmental issues, etc. (Sharma, 2014).

According to sharma (2014), urban water demand consists of domestic, commercial and industrial, public use, miscellaneous (system cleaning, losses, fire demand) components. The domestic component reflects the populations' needs and consumption patterns, while the public and miscellaneous use determines the level of public awareness and system maintenance. However, commercial and industrial demand varies seasonally and annually.

Water demand estimations are usually based on measurements on the consumer side. These measurements, often, do not include leakages along the distribution system, since water meters are installed at sercice connections at the entrance of the households. This can often lead to the inaccurate demand estimation. For that reason, the measurements at various supply points within the system should be established with the purpose of taking more accurate water demand figures.

A proper analysis, including quantification and projection of water demand, is fundamental for an appropriate water supply infrastructure. If this is not done properly, it can result in serious issues, as well as difficulties and calamities in the water supply system operation. Those difficulties are often reflected in insufficient or overestimated capacities and in incorrect dimensions of the components of the supply system, which may provide the consumers with unreliable and inadequate provision of water.

Household water demand has been extensively analyzed in developing countries, in particur to provide price and income elasticities measures. In these countries, almost all households get a connection to the water network and tap water is usually the unique source of drinking water, in general of satisfactory quality. These characteristics make the estimation of a water demand function relatively straightforward.

Water demand projection has been developed and applied over the last decades due to a variety of purposes. Mainly, researchers identify it as useful to understand spatial and temporal patterns of water use in the future. Due to water crisis in many regions around the world (UNESCO, 2009), prognosis of water consumption is of vital importance for water supply companies.

Several methods are used for the estimation of future urban water demand, icluding extrapolating hitoric trends, correlating demand with socio-economic variables, or more detailed simulation modelling (Donkor et al., 2012).

2.8 Water Distribution Network Building and Model Setup

The approach to building the model is to sketch out the system practically on existing topographic maps. The concept of a network is fundamental to a water distribution model. The network contains all of the various components of the system, and defines how those elements are interconnected. Networks are comprised of nodes, which present features at specific locations within the system, and links, which define relationships between nodes.

Water distribution models have many types of nodal elements, including junction nodes where pipes connect, storage tank and reservoir nodes, pump nodes, and control valve nodes. Models use link elements to describe pipes connecting these nodes. In addition, elements such as valves and pumps are sometimes classified as links rather than nodes. Intelligent use of element labeling can make it much easier for users to query tabular displays of model data with filtering and sorting commands. Rather than starting pipe labeling at a random node, it is best to start from the water source and number outward along each pipeline. In addition, just as pipe elements were not laid randomly, a pipe labeling scheme should be developed to reflect that.

2.8.1 Water Distribution Modeling

2.8.1.1 Water CAD

Water CAD is a powerful, easy to use, which is:

a) A water distribution modeling software,
b) Used in the modeling and analysis of water distribution systems,
c) Used for firefighting flow and constituent concentration analysis, energy consumption and capital cost management, and popular for water supply design.

Water CAD provides sensitive access tool needed to model complex hydraulic situations. Some of the key features allow us to:

a) Perform steady state and extended period simulations
b) Analyze multiple time-variable demands at any junction node.
c) Quickly identify operating inefficiencies in the system.
d) Perform hydraulically equivalent network skeletonization including data scrubbing, branch trimming, and series and parallel pipe removal and efficiently manage large data sets and different "what if" situations with database query and edit tools.

2.8.1.2 Water Distribution Simulation

Simulation refers to the process of imitating the behavior of one system through the functions another.

Simulation can be used to predict system responses to under a wide range of conditions without disrupting the actual system, and solution can be evaluated before time, money, and materials are invested in a real world project.

There are two most basic types of simulations that a model may perform, depending on what the modeler is trying to observe or predict. These are:

a) Steady state simulation
b) Extended period simulation (EPS)

a) Steady State Simulation

It computes the state of the system (flows, pressures, pump operating attributes, valve position, etc) assuming that hydraulic demands and boundary conditions do not change with respect to time. A steady-state simulation provides information regarding the equilibrium flows, pressures, and other variables defining the state of the network for a unique set of hydraulic demands and boundary conditions.

Steady-state models are generally used to analyze specific worst-case conditions such as peak demand times, fire protection usage, and system component failures in which the effects of time are not particularly significant.

In general, this type of analysis is used to determine the short-term effect of demand conditions on the system (Tomas, et al., 2003).

b) Extended Period Simulation

Extended period simulation tracks a system over time, and it is a serious of linked steady state run. The need to run extended period simulation is because the system operations change over time.

a) Demands vary over the course of the day.
b) Pumps and wells go on and off.
c) Valves open and close.
d) Tanks fill and draw.

Depending on the purpose of the analysis, the most common simulation duration is typically a multiple of 24 hours, because the most recognizable pattern for demands and operations is a daily one.

Therefore, regardless of project size, model-based simulation can provide valuable information to assist an engineer in making well informed decisions (Tomas, et al., 2003).

2.9 Model Calibration and Validation

Calibration is the process of making minor adjustments to the input data, or base data until the results or output are accurately simulated to the field conditions within an acceptable range of accuracy. For the majority of water distribution models, calibration is an iterative procedure of parameter evaluation and refinement, as a result of comparing simulated and observed values of interest. Model validation is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions which can affect model results and demonstrate the ability to predict field observations for periods separate from the calibration effort. Further, according to Tomas, et at., 2003; hydraulic model calibration is the necessary process of modeling and it is calibrated in order to have better confidence, understanding and identifying errors made during the model building process.

Further, according to Tomas, et al., 2003; hydraulic model calibration is the necessary process of modeling and it is calibrated in order to have better confidence, understanding and identifying errors made during the model-building process.

Pressure calibration

Collecting pressures data throughout the water distribution system used to indicate the level of service. Pressure readings are done using pressure gauge commonly taken at pump stations, storage tanks, reservoirs, fire hydrants, home faucets, air release and other types of valves. However, different factors can contribute to deviation between model simulation and actual field data. Therefore, calibration can be accomplished by adjusting only internal pipe roughness values or estimates of nodal demands until an agreement between observed and computed pressures and flows is obtained. The basis for this claim is that unlike pipe lengths, diameters, and tank levels, which are directly measured, pipe roughness values and nodal demands are typically estimated, and thus have room for adjustment (Tomas, et al., 2003).

2.10 Drinking Water Quality

Drinking water starts its journey within catchments, and is subsequently purified at treatment plants and delivered through distribution systems. Before deliver to distribution system it must meet the highest quality standards, subsequent treatment processes must be done at place of treatment (Solomon, 2011).

Water supplies, especially in developing countries, have been focused on quantity at the expense of quality and there are calls for marked improvement in quality-better management of chemicals and microorganism content (Barrow, 2005). It is important to note, however, that issues of water quality cannot be considered separate from water quantity. In assessing the quality of drinking water, most consumers usually rely completely upon their senses. Water constituents may affect the appearance, smell or taste of water, thus, the consumer evaluates the quality and acceptability essentially on these criteria. However, we can no longer rely entirely upon our senses in the matter of quality judgment. The absence of any adverse sensory effects therefore does not guarantee the safety of drinking water.

In the submission on the drinking water quality control in small community supplies, WHO explains that although in the rural areas of developing countries, it is expected that a great majority of water quality problems are related to bacteriological contamination, a significant number of very serious problems may occur as a result of chemical contamination of water sources from agricultural practices and malpractices. The traditional emphasis on chemical indicators of water quality must be supplemented by more comprehensive indicators based on the total properties of water body including chemical, physical and biological parameters. It must also be recognized that fresh water quality is impacted directly by natural and human activities outside the water sphere such as land use practices, erosion and deforestation. Some are also tied to acid deposition or natural contamination.

2.10.1 Drinking Water Quality Parameters

2.10.1.1 Physiochemical quality of water

The parameters that were considered as part of this study are discussed below.

PH

The PH of water is a measure of how acidic or alkaline (basic) the water is on a scale of 0 to 14. Pure distilled water is neutral with a PH of 7. PH measurement below 7 indicates that the solution is acidic containing more H^+ ions than OH^- ions. Measurement above 7 indicates that the reverse situation exists making the water alkaline. It is important to note that for every one unit change on the PH scale, there is approximately a ten-fold in how acidic or alkaline the sample is. The usual PH for fresh water aquatic system is 6 to 9 with most water ways around PH is an indicator of existence of biological life as most of the thrive in a quite narrow and critical PH range. In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7 (Gaur, 2008). Darko-Mantey et al., (2005), did a study on drinking water from different sources and observed a PH range of 6.1 to 7.2. Though PH has no direct effect on the human health, all the biological reactions are sensitive to variation of PH. For most reactions as well as for human beings, PH value 7.0 is considered as the best and ideal.

Total Dissolved Solid (TDS)

It refers to matter dissolved in water or wastewater. TDS is the portion that passes through a filter.

The TDS in water consists of organic salts and dissolved materials. In natural waters, salts are chemical compounds comprise of anions such as carbonates, chlorides, sulphates and nitrates (primarily in ground water), and cations such as potassium, magnesium, calcium and sodium. In ambient conditions, these compounds are present in portions that create a balanced solution (http://www.duluthstreams.org). WHO, however, recommends the low level of the latter as a guideline value for TDS.

Total Hardness

Water hardness is a traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather, and also leads to scaling of hot water pipes, boilers and other household appliances. Water hardness is caused by dissolved polyvalent metallic ions. In fresh waters, the principal hardness causing ions are calcium and magnesium; strontium, iron, barium and manganese ions also contribute.

In areas with hard water, household pipes can become clogged with scale; hard water also cause incrustations on kitchen utensils and increase soap consumption. Hard water is thus both a nuisance and an economic burden to the consumer. Public acceptance of hardness varies among communities; it is often related to the hardness to which the consumer has become accustomed, and in many communities hardness greater than 200mg/L is tolerated. However, waters with hardness in excess of 500mg/L are unacceptable for most domestic purposes.

Chloride, Cl^-

Chlorides in groundwater and surface water can be naturally occurring in deep aquifers or caused by pollution from sea water, brine, or industrial or domestic wastes. Chloride in water may be considerably increased by treatment processes in which chlorine or chloride is used. Chloride concentrations in excess of about 250mg/l can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250mg/l.

Fluorides, F^-

Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. Traces of fluorides are present in many waters; higher concentrations are often associated with underground sources.

Total Alkalinity

Alkalinity is a measure of the ability of a solution to neutralized acids to the equivalent point of carbonate or bicarbonate. Alkalinity can also be defined as a measure of the presence of bicarbonate, carbonate or hydroxide constituents. The alkalinity is equal to the stoichiometric sum of the bases in solution.

Total Suspended Solid (TSS)

It refers to matter suspended in water or wastewater, the greater the amount of total suspended solids (TSS), the murkier it appears and the higher the measured turbidity. It is the portion of total solids retained by a filter. Surface water and shallow wells have been known to be affected by flooding, effluent, discharge and infiltration (Nduka et al., 2008).

The greater the amount of Total Suspended Solid (TSS), the murkier it appears and the higher the measured turbidity. TSS is an indication of the amount of erosion that took place. (http://www.duluthstreams.org).

Turbidity

For water to be aesthetically accepted, its clarity must be ensured. Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity may be due to organic and/or inorganic constituents. Organic particulates may harbor microorganisms. Thus, turbid conditions may increase the possibility for waterborne diseases. Nonetheless, inorganic constituents, have no notable health effects. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body. The excess nutrients may results in algal growth.

Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 0.1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004).

2.10.1.2 Microbiological quality of water

Coliform bacteria

The microbial quality of water is determined by the presence of bacteria indicative of feacal (sewage) contamination, which called total coliforms. Coliforms occur naturally in the soil and in the gut of humans and animals. Thus, their presence in water may indicate contamination. The presence of coliform bacteria in well water may be as a result of surface water infiltration or seepage from a septic system (Obiri-Danso et al., 2008).

Total coliforms are a group of bacteria commonly found in the environment, for example in soil or vegetable, as well as the intestines of mammals, including humans. Total coliform bacteria are not likely to cause illness, but their presence indicates that your water supply may be vulnerable to contamination by more harmful microorganisms.

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CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location of the study area

Sebeta is situated in the Awash River Basin, a basement depression being its sub-drainage. It is located in the Oromia Special Zone Surrounding Finfinne of the Oromia Region, western Shewa Zone and 20km from Addis Ababa along the road to Jimma. It is located in the central highlands of Ethiopia within latitude 8^0 52' to 8^o 57'N and longitude 38^0 33' to 38^0 42'E with an elevation ranging from 2050-2500 meters above mean sea level. Hills and steep slopes are bounding the town in the northwestern, northern and eastern and southern part with moderate and gentle slopes spanning to the town. Generally; the town lies within the semi-circular ridge of hills to the east, north, and west which provide surprising natural vitals and delightful views from the center.

The mean annual precipitation and temperature are about 1200mm and 25^oc respectively. As per the hydro-meteorological data, Sebeta is one of the regions in the country with potentially moderate rainfall throughout the year.

(Source: National Meteorological Service Agency)

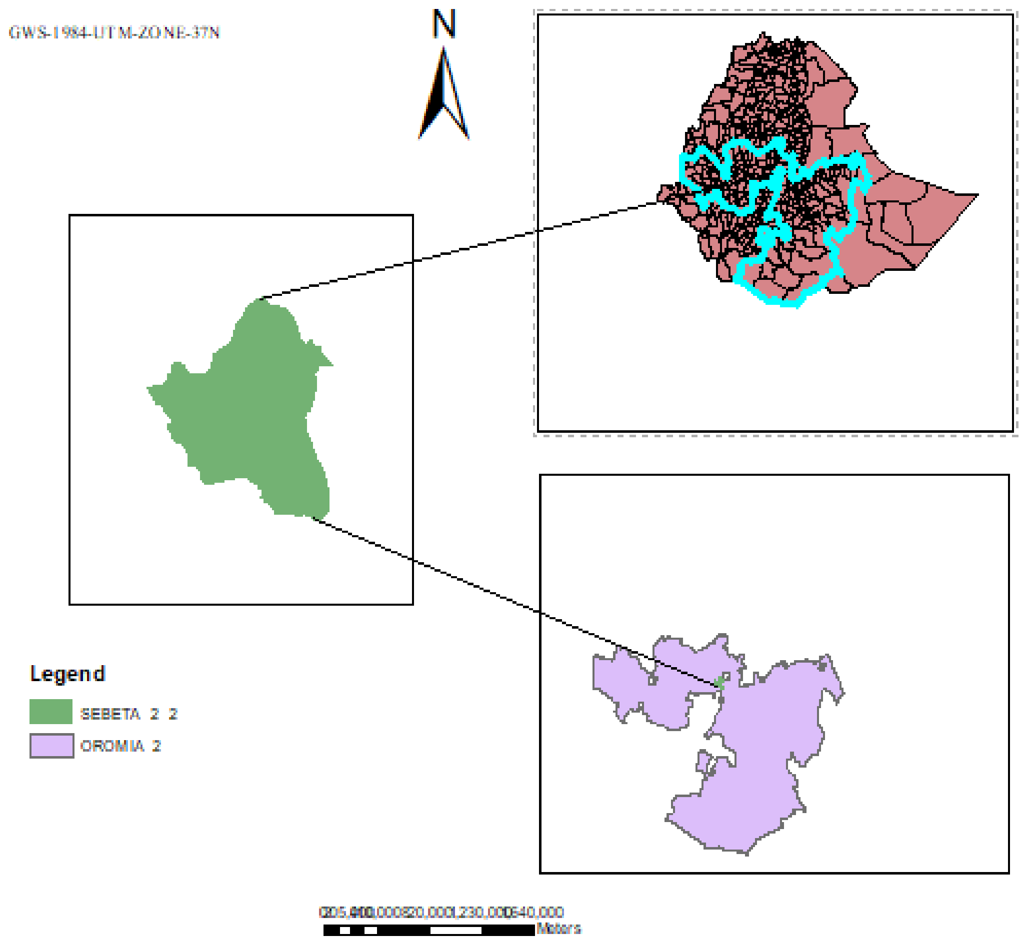


Figure 3.1: Location of the study area

Because of its vicinity to Addis Ababa, the town has high growth potential and industrial development activities, this situations enhances the need for development of urban infrastructure such as water, electricity and communication facilities.

3.2 Socio-Economic Structure

3.2.1 Demography

Sebeta town is one of the dynamic areas of Oromia that is experiencing at high degree of urbanization and fast development. It is one of the areas in Oromia region that has changed from a mere rural locally to a big and modern developing urban center in a very short period of time. The increasing population and living standards running parallel with an increasing demand for potable water, it is obvious that a sound strategy for a strict control of water use and reliable future demand estimation are crucial to designing of a viable water supply scheme. Future demand projection in turn depends on forecasting expected future population based on statistical models considering possible potential variations and appropriate adjustments to reflect possible future changes. In light of these facts, therefore, the study of population size and its development and distribution over the project area has been strictly considered.

The 2007 census revealed that the town's area is more than double of the 1994 census, which is far beyond the anticipated expansion. This mainly attributes to the fact that the regime change in the 21st century has inaugurated a platform of liberalization and free market policies that attracted the attention of investors and developers. Different sources have also made known that between 1994 and 2007 extraordinary high rates of growth were observed with a comprehensible trend of increasing population figure. Deriving population projections is, often, intricate for areas like Sebeta, which is experiencing such unexpected rate of population explosion. Besides, projection becomes less reliable when it is made for a small portion of the area than for the whole geographic area. This is mainly because of the fact that projections made for large geographic areas use large population base that will be less likely to exhibit short-term variation. Likewise, projections made for longer target year of the project become statistically more reliable than that made for shorter duration as inputs to the projection are based on calculations rather than actual figures. It is observed that currently Sebeta town hosts the development of different infrastructures, industries and housing projects owned by government and private investors. It is apparent that the development has a direct bearing on the water consumption of the town and hence, every determining factor has been considered in light of their effects on the water demand of the town. According to Sebeta town administration office report, the current number or base population in the year 2016 of the town is 234,799.

3.2.2 Household Information

According to the MS consulting PLC design report, the number of families per household is between four and six which is shown in Table 3.1. Average family size per household is found to be 4.92.

Table 3.1: Family Sizes per household

Family Zize	Percent of population the total population
Less than four	0
Four	7.9
Greater than five	91.1

Source: MS consulting design report

The average family size recognized in the survey study is somewhat higher than the size scrutinized by the 2007 population poll of CSA, 4.8 members per family head for Oromia region. In this study the CSA value approximated to 5 is used.

3.3 Existing sources and transmission mains

The whole of the town, except the small area served by existing borehole (Jember, Alfurkan, Alemgena ERA, Walate Condominium, Meta, Walate and Furi) and Sebeta spring pumping station with associated service reservoirs located at Sebeta and Alemgena fall under harsh water deficit. About 7km transmission mains with diameter of 150mm convey water from Sebeta pumping station to service reservoirs and from borehole sites to the respective distribution networks from where majority of the currently served villages are fed either through pumping to the commanded areas or by gravity from reservoirs to the lower areas. The existing boreholes were widely dispersed and the water is directly pumped to the distribution pipe network which was developed through time.

3.4 Water supply coverage analysis

The water supply coverage of the town has been evaluated based on the average per capita consumption and by mode of service. The average per capita consumption has been derived from the yearly consumption that was aggregated from the individual domestic water meters. Based on the average per capita water consumption, the distribution of number of domestic mode of service has been also evaluated. Statistical analysis was used to evaluate the supply coverage for the entire town.

3.4.1 Average daily per capital consumption

The volume of water consumed for domestic purpose has been aggregated to all kebeles of the town so as to analyze the distribution of the water supply coverage among different localities. The annual consumption data has been converted to average daily per capita consumption using the number of population. The average daily per capita consumption of town was derived using the following expressions:

$$\text{Capital consumption (l/person/day)} = \frac{Annual\ consumption\ (m^3)\ x\ 1000\ l/m^3}{Population\ number\ of\ the\ town\ x\ 365} \quad \ldots\ldots\ldots\ldots\ldots(3.1)$$

3.4.2 Mode of service

The level of water supply service greatly affects the water demand of users. If the mode of service is efficient as house connection, the demand for water is also very high due to consumption for multipurpose functions such as toilet flushing, laundry machines and bathing rooms. The water demand of the users is decreasing as the level of mode of the water supply decreases. In general, the level of service to be provided to consumers depends on the socio-economic development of the resident. Consequently, the following common three types of service levels have been adopted for Sebeta town.

i) House Connection (HC)

ii) Yard Connection (YC) and

iii) Public Fountain (PF).

3.5 The Materials Used

3.5.1 Source of Data

To acquire the required information needed to meet the objectives of the study, both primary and secondary data collection techniques were employed. The primary data gathering technique include household survey questionnaires, key informant interviews, and personal observation and informal discussion and water quality laboratory test, elevation data, while secondary data collection method is from related literature reviews, annual reported papers, and the town's water supply service office existing documents, related journals and from internet.

3.5.2 Instruments of data collection

One of the main steps in conducting a research is to collect data that enable a researcher to reach suggested solutions for the problems identified. In this study GPS, questionnaire and interview method were employed depending on the situation in which they were applied.

GPS

Hand GPS was the instrument used to collect the required elevation, coordinates data during pressure reading. Pressure readings were done using pressure gauge which is commonly taken in the selected points of distribution system. The kind of GPS used was, hand GPS which called GPS 60. In addition, leveling was used for data collecting which was used to cross-check the data collected with GPS. The data collection picture on site by using GPS and leveling is attached in appendix K and L respectively.

Questionnaire

Questionnaire which is the major data collection instrument was used in this study. It also used to obtain the objective of assess the availability, distribution, quality, water tariff and consumption of water of the town. It was prepared to validate the information gained through documents and interview. The real questionnaires and the respondent's answer is attached in appendix M and N respectively.

Interview

Most of the questions were focused on the availability, distribution and consumption of water supply in Sebeta town and the status of the existing water supply and demand in the town. From Sebeta town water service office technique some employers and experts were selected for this interview since these employers may give significant information for the investigator about the production, distribution and consumption of water in the town.

3.6 Methods of Data Collection

3.6.1 Sampling Technique

The sample respondents' were selected by random sampling from the lists of name of households in the town administration or kebele.

3.6.2 Primary Data Collection

Data collection is the most significant part in research work. To do this work, the data were collected with regard to the necessary input parameters of model simulation. On the other hand the data collection techniques were done by physical observation or field visit and by direct contact with the consumers.

3.6.3 Secondary Data Collection

The data of water production and water consumption were obtained from different documents of the the Sebeta town water supply office, design reports from the previous consulting office were used as the secondary data.

3.7 Summary of Data Collected

3.7.1 Source of Water

The source of water for Sebete town is ground water source. These source were a total of twenty seven potential boreholes which have been drilled within the town at different times and Sebeta spring.

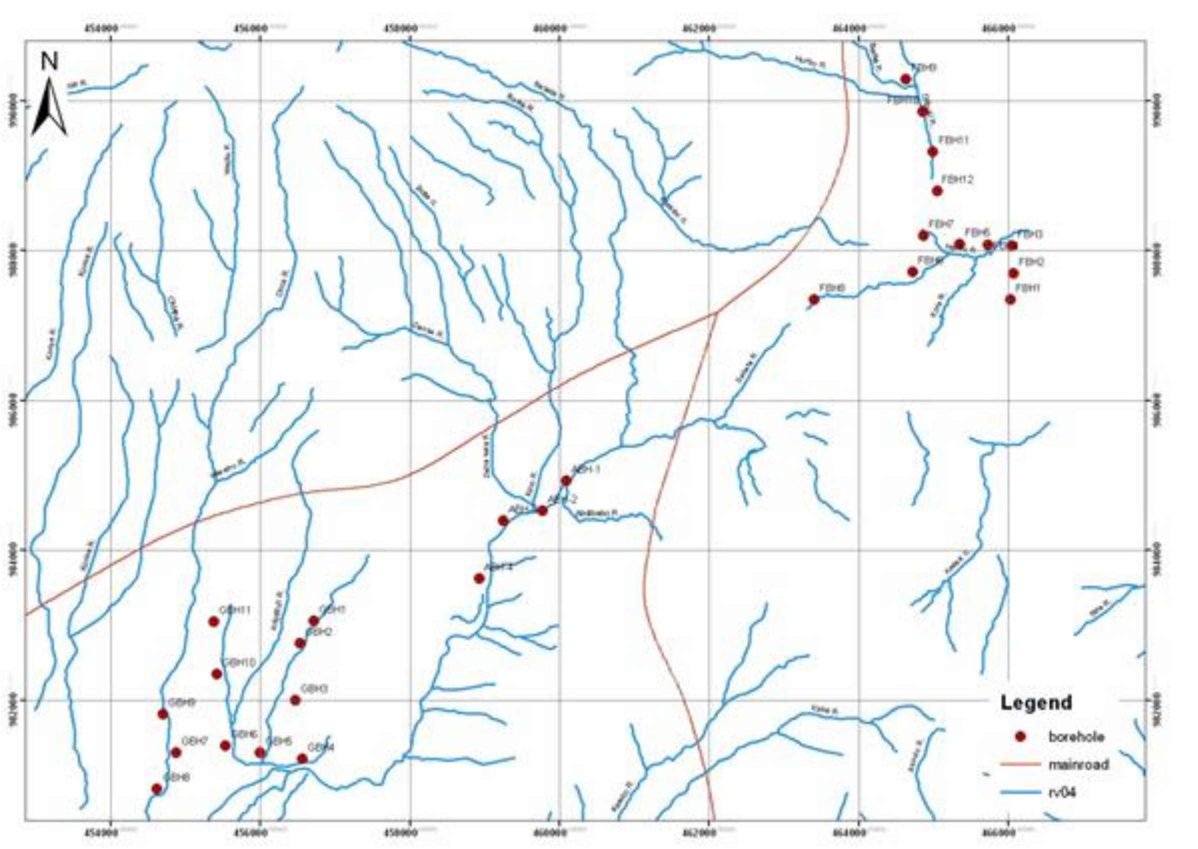
The proposed water supply scheme of the study area is supplied from the existing Sebeta spring water and from the 27 proposed boreholes in Furi, Alemgena and Geme well fields. There are also privately owned boreholes envisaged to supplement the supply from the spring source and newly proposed boreholes. All sources proposed to supply the pressure zones found in the study area have been identified. Table 3.2 shows pressure zones and their respective sources.

Table 3.2: Sources of water for the pressure zones

Subsystem	Supplied from
Dima	From seven boreholes proposed to be drilled from Geme well field.
Sebeta	From the existing Sebeta spring and backup from four boreholes drilled in Geme well field.
Alemgena	From the existing Sebeta spring and backup from four boreholes drilled in Alemgena(Roge) and eight boreholes from Furi well field.

Walate	From four boreholes drilled in Furi well field.

(Source: Sebeta Town Water and Sewerage Authority)



(Source: Sebeta Town Water and Sewerage Authority)

Figure 3.2: Sources of water for all pressure zones in the study area

3.7.1.1 Sebeta Spring Sources and Related Works

According to this study, most part of Sebeta and Alemgena subsystems are supplied from Sebeta spring through transmission main drawn to the respective service reservoirs located in the subsystems from the spring pumping station. Areas located at higher levels, including Dima and Walate receive no water due to insufficiency of the spring water and lack of transmission and distribution lines to these areas from the spring pumping station. Table 3.3 summarizes pressure zones supplied from Sebeta spring.

Table 3.3**:** Subsystems supplied from Sebeta spring source and related works

Subsystems	**Service Reservoir**	**Source**	**Supply System**	
			Gravity	**Pumping**
Sebeta	SR	Sebeta Spring		X
Alemgena	AR	Sebeta Spring		X

(Source: Sebeta Town Water and Sewerage Authority)

In the proposed scheme, there are two transmission lines drawn from Sebeta spring to the respective service reservoirs. The first point is where the transmission line is drawn to Sebeta reservoir of Sebeta subsystem; the second is where the transmission line to Alemgena reservoir of Alemgena subsystems from the spring water pumping station through 150mm transmission main. The yield of the spring water is found to be about 13l/s and serve the two subsystems in succession.

3.7.1.2 Borehole

In general, there are twenty seven boreholes with submersible pumps in Sebeta town and currently only some of them are operational. The summarized borehole is shown in Appendix A.

3.7.2 Borehole Collectors

Collectors are conduits used for the conveyance of water from source to transmission mains. Borehole collectors may be categorized as main or subsidiary collectors. Subsidiary collectors are those conduits, which transport water from each borehole to main collector, and main collectors are conduits, which link the water received from subsidiaries to the transmission mains.

3.7.3 Transmission/Transfer Mains

A transmission main is a conduit used for the conveyance of water from collectors to reservoir, and transfer main is that part of the system that conveys water from reservoir and/or booster station to another reservoir. In the proposed scheme, there are a number of transmission mains and one transfer line from boreholes and Sebeta booster station to the respective service reservoirs. In this system, there are transmission mains conveying water from boreholes in Furi, Alemgena and Geme well fields to the nearby service reservoirs. The transfer main is meant to transmit water from Sebete booster to Sebeta service reservoir by boosting.

3.7.3.1 Main Pipes Alignment

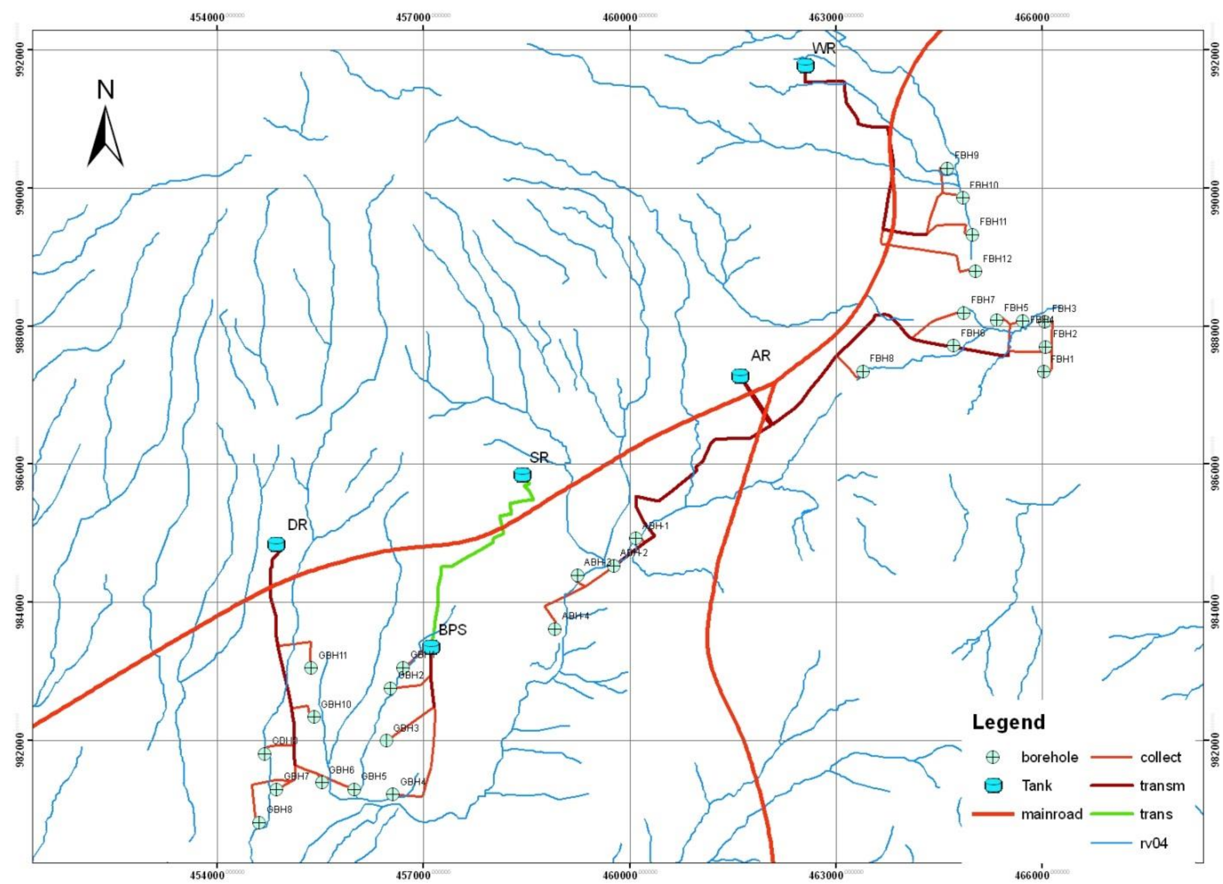
There are seven transmission and one transfer mains identified in the study area. The first and second transmission mains convey water from the Sebeta spring pumping station to Sebeta and Alemgena service reservoir while the third, fourth, fifth, sixth and seventh transmission mains conveyed water from the borehole collectors located at Geme well field to Dima service reservoir, Geme well field to Sebeta booster station, Alemgena well field to Alemgene service reservoir, Furi well field to Alemgena service reservoir and Furi well field to Walate service reservoir. The transfer main runs from Sebeta booster station to Sebeta service reservoir.

Transfer Main from Booster Station to Reservoir

This transfer line begins at the foot of Sebeta booster station, continues straight to north along the left side of the proposed road until it joins the main asphalt road to jimma, follow right side of the road until it reaches road branching to high school where it crosses through culvert to left of asphalt road, turn right to the bus station and follow the propose road to the existing 200 m^3 service reservoir site located behind St. Gabriel church where it ends.

Mains from the Boreholes

These transmission mains convey water from the production wells in the study area to the nearby service reservoirs. The majority of the boreholes are concentrated in Geme and Furi areas and there are a number of boreholes in Alemgena well field areas. The routes of all the mains are selected following the road master plan of the town to avoid crossing through private properties and protected areas. These mains are done by using water CAD modeling and export to ArchGIS 10.4.1. The following figure shows the borehole collectors, transmission and transfer mains from the various sources in the study area to their respective reservoirs.



(Source: Sebeta Town Water and Sewerage Authority)

Figure 3. 3: Detail of borehole collectors, transmission and transfer mains in the study area

3.8 Sizing the main and distribution pipe line of each subsystem

3.8.1 Dima Subsystem

Pipe alignments, materials and sizes

The alignments of pipes in the distribution system are adopted based on the alignments of road master plan of the town. However, appropriate amendments to the areas under previous design have been made on the routes of the pipes in order to minimize the lengths and to reduce the number of road crossings as much as possible. This makes the system more efficient and cost effective.

As specified in the design criteria, the choice of material type is based on the diameter of the pipes that is directly related with the cost of supply and installation. For higher diameter pipes, greater than 300mm, DCI pipes are more economical than uPVC pipes and the reverse for pipes with diameter less than or equal to 300mm. Therefore, based on the proposed diameter of pipes, both DCI and uPVC pipes have been used in the system. Besides, pipes with diameter less than 80mm have been used in certain sections of the distribution system to solve the problem of velocity drop less than the minimum recommended value. For these sections, HDPE/GI pipes are recommended.

When modeling the distribution system of the subsystem, first fix pipe sizes that are able to transfer the required flow were assigned for each pipe. Then the model is analyzed and checked for pressure adequacy and velocity. If there are discrepancies between the recommended values and the result of the analysis, the pipes are re-sized to attain the acceptable values. This process is repeated until the nodal pressures and velocity of flow in pipes become reasonably acceptable. The final pipe inventory of this subsystem is presented in Appendix B.

3.8.2 Sebeta Subsystem

Pipe alignment, materials and sizes

Like the other subsystems, the pipe materials of this pressure zone are DCI for diameters greater than 300mm and uPVC for smaller ones up to 80mm diameter. Those pipes with sizes beyond 80mm are recommended to be HDPE/GI pipes. The alignment of pipelines is made following the master plan of the town. Though the extent of existing pipes in the pressure zone is small and insufficient to cater adequate water, they are providing water to the community found in the area. The detail pipe inventory of this pressure zone is presented in Appendix C.

3.8.3 Alemgena Subsystem

This subsystem is envisaged to be supplied from two reservoirs with capacities of 200m^3 existing and with additional 2,500m^3 of Alemgena reservoir.

Pipe alignments, materials and sizes

The alignment of pipelines is made following the master plan road of the town. Though the extent of existing pipes in the pressure zone is small and insufficient to cater adequate water, they are providing water to the community found in the area. In this subsystem, pipes with diameter ranging from 50mm to 500mm have been used. Pipes with diameter less than or equal to 300mm (inclusive) are recommended to be uPVC and pipes greater than 300mm are considered to be DCI pipes. There are also HDPE/GI pipes having diameter of less than 80mm. The pipe inventory of the subsystem is presented in Appendix D.

3.8.4 Walate Subsystem

Pipe alignments, materials and sizes

Like in other subsystems, the pipe materials are selected based on the diameter of the proposed pipes. All pipes have diameter greater than or equal to 80mm and either uPVC or DCI have been recommended based on their diameter. The pipe inventory of the pressure zone is presented in the Appendix E.

3.9 Reservoirs

The service reservoirs were designed to balance peak hour demand fluctuations and to ensure continuous supply during system maintenance or power cutoff. Attempts also made to locate a reservoir close to the distribution area in order to reduce the laying of excessive and as much as possible low or moderate pipelines. The reservoirs are situated at a higher elevation than the distribution system in order to secure gravity flow with due care not to exceed allowable pressure during peak hour demand conditions at the lowest points in the subsystem.

3.9.1 Sebeta reservoir

This reservoir is supplied from the 150mm Sebeta spring transmission main and the 300mm Geme well field transfer line and dedicated to balance the demand and supply fluctuation of Sebeta subsystem. The capacity and internal diameter of this reservoir is 1,500m^3 and 21m respectively, which were used in the water distribution system of the town.

3.9.2 Dima reservoir

This reservoir was designed to be supplied from boreholes located in Geme well field directly and intended to balance the supply demand fluctuation and fire-fighting requirement of Dima subsystem. The capacity of this reservoir is 2.500m^3 with a diameter of 21m.

3.9.3 Alemgena reservoir

This reservoir is supplied from the 150mm Sebeta spring transmission main and the 250mm and 350mm o Alemgena and Furi well field transmission mains, respectively, and dedicated to to balance the demand and supply fluctuation of Alemgena subsystem. The capacity of this reservoir is 2,500m^3 and the internal diameter is 25m.

3.9.4 Walate reservoir

This reservoir was desgned to be supplied from boreholes located in Furi well field directly and intended to balance supply demand fluctuation and fire-fighting requirement of Walate subsystem. The capacity and internal diameter of this reservoir is 1000m^3 and 17m respectively.

Elevation data

Setting elevation is one of the significant requirements to simulate the hydraulic characteristic of water in distribution system. Most of the elevation data was obtained from the town water service office which was prepared as the design report of Sebeta town water supply system, means from existing document. But, elevation data for expansion area in the town were served in the field using surveying instrument, global position system (GPS). Elevation data for service reservoir site is summarized in the table below.

Table 3.4: Elevation data

Zone	Reservoir	Reservoir Water Level		Elevation of Points		Static Heads	
		TWL	BWL	Highest	Lowest	Max.	Min.
Dima	DR Res.	2217	2211	2187.86	2079.15	137.85	23.14
Sebeta	SR Res.	2313.69	2308.69	2287.33	2177.66	136.03	21.36
Alemgena	AR Res.	2352.73	2346.73	2324.12	2241.77	110.96	22.61
Walate	WR Res.	2451.25	2446.25	2427.57	2327.88	123.37	18.68

(Source: MS Consulting design report).

3.10 Sample size determination method

In order to obtain quantitative data from the respondents, sample size (N_i) that could be involved in house hold survey was calculated. Therefore, the sampling size was calculating by using the following statistical formula (CochranWG, 1977).

$$Ni = \frac{N * Z2 * P * Q}{W2 * (N-1) + Z2 * P * Q} \quad \text{...} (3.2)$$

Where;

N_i Sample household

N Total number of household

P Proportion (50%)

Q 1-P

Z 95% confidence interval (1.96)

W 5%

3.11 The method used in the analysis of hydraulic performance

It is necessary to analyse pipe networks of a given distribution system in order to determine the pressure and flow availability in any section of the system and to suggest ways to improve up on the same if found in adequate.

In this case the hydraulic analysis of the whole water supply system of Sebeta town was controlled by "WATERCAD" software.

The computer model was the foundation of network analysis. In order to make the analysis representative and dependable, an accurate model of the distribution system must be established. For this reason, computer model preparation is a critical early step in the process of network analysis.

Input parameters for Water CAD Model

The two most important data, network base data and operating parameters are first collected and synchronized for the network analysis. For modelling purposes, these system elements were organized into the following categories. (Water CAD: USER MANUAL, 2013).

Table 3.5: Input parameters and primary purposes of water CAD model

Element	Type	Primary modelling purpose	Input data
Reservoir	Node	Provides water to the system	Hydraulic grade line (water surface elevation)
Tank	Node	Stores excess water within the system and releases that water at times of high usage	Base Elevation, Max. elevation, Min. elevation and diameter
Junction	Node	Discharge the demand required or recharge the inflow water from/to the system	Elevation
Pipe	Link	Transport water from one node to another	Elevation, Diameter, Material and Roughness coefficient
Pump	Node	Provide energy to the system and raise the water pressure to overcome elevation differences and friction losses	Elevation, pump definition (Characteristics of max. operation and design discharge and head efficiency)
Valves	Node	Controls flow or pressure through a pipe and results in a loss of energy in the system	Elevation, Diameter and Valve

(Source: Water CAD: USER MANUAL, 2013)

In addition to this different equation was used. These equations are as follows:

Hazen – Williams equation

Hazen-Williams equation is an empirically based equation and the most frequently equation used in the design and analysis of water distribution networks, it was developed by the experiment and used only for water within temperatures normally experienced in potable water systems. The Hazen-Williams equation was formed in the early 1900's by Gardner Williams and Alan Hazen.

$$Q = 0.278CD^{0.63}S^{0.54} \quad \text{......}(3.3)$$

$S = H_f/L$ & $H_f = S * L$

Where, C= Coefficient that depends on the material and age of the pipe given.

S= Hydraulic gradient; m/m

Q= Quantity of flow, m3/m

D =Internal diameter of pipe

Darcy-Weisbach equation

H_f = f * L/D * V_2/2g……………………………………………………………………….(3.4)

Where, H_f-Head loss in meter

f- Friction factor

L-Length of pipe in meter

V-Velocity of flow, in meter per sec

g- Acceleration due to gravity.

Manning equation

Q= 1/n*A*$R^{2/3}S^{1/2}$…………………………...……………………………………………(3.5)

Where, n-Coefficient of roughness

X-sectional area

R-Hydraulic radius

S-longitudinal slope

3.12 Distribution System Analysis

3.12.1 Hydraulic Modeling Software

The hydraulic modeling software water CAD 6.5 simulation was carried out for the purpose of pressure regime for customers demand, velocity, and head loss and overall systematically studying and better understand network operation.

The use of the above software is recommended that the up to date Water CAD 6.5 software for an unlimited number of pipes is appropriate for the development of the skeletal and all mains models of Sebeta water supply network.

3.12.2 Model Analysis

Analysis of the model of existing system has been made by running the model at current year daily average, at peaking and temporal variations of demand with different scenarios.

Steady-State Analysis

The model has been performed in steady state run for the average daily demand, which is the demand at every node not changing throughout 24 hours of a day. The software simulates Steady-State hydraulic calculation based on mass and energy conservation equations principle.

Extended-Period Simulation

The system conditions have been computed over 24 hours with a specified time increment of one hour and starting model run time at 7:00 A.M. The software simulates non-steady-state hydraulic calculation based on mass and energy conservation equations principle.

The model can be simulated for every one-hour time setup in the 24 hour duration. However, for the analysis the peak and minimum hours, demand has been simulated to identify the current problems of the system.

3.13 Model calibration and Validation

For model calibration and validation effort data were collected from field visits. The computed parameters of a model and actual field observation do not always have the same value. Therefore, before discussion about the simulated model results, the entire model data quality must be analyzed by calibration and validation technique. In this study, the model data quality analysis was done by comparing and calibrating the computed pressure data with the observed one. According to Tomas, et al., (2003), the calibration process was performed by adjusting sensitive parameters related with flow; like pipe roughness coefficient and water demand until it was become within the acceptable limit of 85% of field test measurements (it should be within ±0.5% of the maximum head loss across the system, whichever is greater) and then finally it was validated manually using the correlation coefficient (R^2) method using Microsoft Excel sheet.

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}} \qquad \text{……………..(3.6)}$$

3.14 Sampling for the analysis of water quality

Water samples were collected from six different household connection and public fountain, namely, Sebeta household tap, Alem Gena household tap, Walate household tap, Dima household tap, Sebeta public fountain and Dima public fountain. At each sampling site, the sample was collected into 500 ml sterilized bottles and transported to the laboratory for analysis within 24 hours. All the pictures of instruments, reagents and during working on water quality laboratory test were attached in appendix: Q and R.

3.15 Water Quality Parameters

The parameters chosen for analysis of water quality for this study are presented as Below:

3.15.1 Physicochemical Parameters

The PH values

In water solution, variations in PH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. PH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. The PH value is determined by measurement of electromotive force of a cell consisting of an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and a reference electrode (usually mercury or calomel electrode).

The instruments used were PH meter with glass and reference electrode (saturated calomel), preferably with temperature compensation and thermometer with least count of 0.5^{o}C.

Rinse and gently wipe the electrodes with solution. If necessary, immerse them into the sample beaker or sample stream and stir at a constant rate to provide homogeneity and suspension of solids. Rate of stirring should minimize the air transfer rate at the air-water interface of the sample. Note and record sample PH and temperature. However, if there is a continuous drift, take a second reading with the fresh aliquot of sample without stirring and report it as the PH value.

Total Dissolved Solids (TDS)

TDS was determined using calibration method in which the sample is vigorously shaken and a measured volume transferred into 500 ml graduated cylinder by means of a funnel. The sample was filtered through a glass fiber filter and a vacuum applied for about three minutes to ensure that water was removed as much as possible. The sample was washed with deionized water and suction continues for at least three minutes. The total filtrate was transferred (with washing) to a weighed evaporating dish and evaporated to dryness on a water bath. The evaporated sample was dried for at least one hour 180^0C. The dried sample was cooled in a desiccator and weighed. Drying and weighing process was repeated until a constant weight was obtained.

Total Hardness

Total hardness is determined by EDTA (Ethylenedaimine Tetraacetic Acid) titration method. A 100 ml of the water sample was put into a 250 ml conical flask. Two drops of Erich Rome black T indicator was added. The content in the conical flask was titrated against a standard EDTA solution (0.01M) until the contents of the flask changed from wine-red to blue at the end point. Titration was repeated until a consistent titer was obtained. The value of the average titer was recorded and at the end point the colour is sky blue.

Chloride Cl^-

A 100ml of the water sample was measured into a 250ml conical flask and 3 drops of potassium dichromate indicator was added to the contents of the flask. The content in the conical flask was titrated against standardized silver nitrate solution, stirring constantly, to end point which is indicated by a permanent red colour. Finally, the titer was recorded.

Fluoride (F^-)

The SPADNS (sulphophenylazo dihydroxynaphthalenedi-sulphonate) colorimetric method is based on the reaction between fluoride and a zirconium-dye lake. Fluoride reacts with the dye lake, dissociating a portion of it into a colourless complex anion (ZrF_6^{2-}) and the dye. As the amount of the Fluoride increases the colour produced becomes progressively lighter. The reaction rate between fluoride and the Zirconium ions is influenced greatly by the acidity of the reaction mixture.

Water sample of 50 ml was measured into a conical flask. Each SPADNS solution 5 ml of and Zirconyl-acid reagent were added. They were mixed well and the absorbance read, by first setting the spectrometer to zero. If the absorbance fell beyond the range of the standard curve, the procedure was repeated using diluted samples.

Total Alkalinity

The instrument used is the PH meter. Pipette 20ml of sample into a 100 ml beaker. If the PH of the sample is over 8.3, then add 2 to 3 drops of phenolphthalein indicator and titrate with standard sulphuric acid solution till the pink color observed by indicator just disappears (equivalence of PH 8.3). Record the volume of standard sulphuric acid solution used. Add 2 to 3 drops of mixed indicator to the solution in which the phenolphthalein alkalinity has been determined. Titrate with the standard acid to light pink color (equivalence of PH 3.7). Record the volume of standard acid used after phenolphthalein alkalinity.

Hence, Total Alkalinity (as mg/l $CaCO_3$) $= \frac{(A+B)*N*5000}{V}$ ………………………(3.7)

Where,

A = ml of standard sulphuric acid used to titrate to PH 8.3,

B = ml of standard sulphyric acid used to titrate from PH 8.3 to PH 3.7,

N = Normality of acid used and

V = Volume in ml of sample taken for test.

Total Suspended Solids (TSS)

Marked evaporating crucibles were heated in an oven and cooled in a desiccator. The clean crucibles were weighed with an analytical balance. 20ml of each of the samples was measured with a measuring cylinder, poured into each crucible and placed on the water bath to evaporate to dryness. Upon drying, the crucible were removed and replaced in an oven at 105 ^{0}C for one hour after which they were cooled in a desiccator for 20 minutes and reweighed using an analytical balance. Then weights were recorded. The differences in the weights were calculated as total solids.

Turbidity

It is based on comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The sample tubes should be of clear and colorless glass. The turbidimeter shall consist of a nephelometer with a light source for illuminating the sample and one or more photo electric detectors with a readout device to indicate the intensity of light scattered at right angles to the path of the incident light.

Turbidimeter calibration-follow the manufacturer's operating instruction. Measure the standards on turbidimeter covering the range of interest. If the instrument is already calibrated in standard units, this procedure will check the accuracy of calibration. Shake the sample to disperse the solids. Then wait until air bubbles disappear. Pour sample into turbidimeter tube and read turbidity directly from the instrument scale.

3.15.2 Microbiological Parameters

Determination of Coliform Bacteria

Water samples from each of the six sampling site were anlysed for the presence of bacteria using the membrane filtration method 100ml of each of the water samples were separately filtered through 0.45μm pore size membrane filter (millipore).

Determination of total coliform (TC) was done by incubating the membrane filter on Hichrome media at 37^{o}C for 24 hours and deternined as colony forming unit per 100ml.

3.16 Estimation of water demand

While designing the water supply scheme for a town or city, it is necessary to determine the total quantity of water required for various purposes by the city. Because to supply water for a town or city, it is necessary to know the amount of demand and used to balance the difference between the supply and demand.

As a matter of fact, the first duty of the engineer is to determine the water demand of the town and to find out the suitable water sources from where the demand can be meet.

In order to arrive at a reasonable value of rates of demand of Sebeta town, it is necessary to estimate the current water demand of each node in the distribution network by following the steps below:

Assigning the total population of the town

Different population forecasting methods are in fact available and can be used for population projection. But their result varies from one method to another. Preference of the method appropriate for particular town needs to consider overall current situations of the targeted town. For fast growing town, where relatively high economic activity is observed and at the same time continuous expansion for town due to various reasons is experienced, exponential population forecasting method is preferably used. To predict the population of the town, it is necessary knowing factors affecting the population distribution, size and growth rate. In Ethiopia, the major factors that influences on the changes in population figure are births, death and migration. All these factors are influenced by family planning practice, war, natural disaster, development of the towns and the socio-economic activities in and around the town. For this study, based on the historical figures, assumptions considered (available of data) and to be precise, the 2016 Sebeta town population figure was used with CSA population growth rate was used for population projection methods.

This method is expressed as follows:

$$P_n = P_o e^{rn} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

Where,

P_n = population at year n

P_o= base year population

e = constant e, the base of natural logarithm

r = population growth rate

n = projection year

Assigning number of peoples in each supply node

The current average number of person in each house was obtained from the revised design report of the town population projection. The total number of houses in the town was identified by dividing the total population to the average number of person in the town. Therefore, in the opened Microsoft Excel Sheet, the entire nodal junction in the system and the number of houses assigned for each node were entered respectively.

Number of people for a supply node =number of house assigned by that node * average number of people in each house…………………………...…(3.9)

Assigning average day water demand of the town

For assessing the average water demand of the town, deterministic water demand estimation method was used. Hence, the annual consumption data has been converted to average daily per capita consumption using the number of population. The average daily per capita consumption of town was derived using the following expressions:

Capital consumption (l/person/day) = $\frac{Annual\ consumption\ (m^3)\ x\ 1000\ l/m^3}{Population\ number\ of\ the\ town\ x\ 365}$ …………….(3.10)

Therefore, the average water demand of the town was calculated by multiplying the per capita demand with the estimated number of population as follow: Q_{ave} = per capita water consumption * total population………(3.11)

Assigning base water demand in each supply node

Once the average day water demand of the system was determined, to calculate base water demand for the particular supply node the following equation was used (Bhadhhade, 2009)

Base water demand for a supply node = (Population served by that node) / (total population of the town) * average day water consumption)......…..(3.12)

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Domestic Water Supply Coverage

Access to water supply may be evaluated using the amount of water consumed and by mode of service. For evaluating the amount of water consumption, the annual water consumption is converted to average daily per capita consumption using the population data of the town. Besides population distribution by mode of service has been also used as elaborated below.

4.1.1 Population Forecasting

The water demand of a particular town is proportionally related with the population to be served. In order to forecast the current population (2017) of the study area based on last population census report population of 2016 which was prepared by Sebeta town administration. Growth rate of 4.2% which was reported by CSA for Sebeta town was used for the current projection.

Applying the growth rate in the exponential model, the urban population of Sebeta town was projected up to year 2037 and is presented in Table 4.1.

An average town population as has been reported by the town municipality in 2016 is 234799.

Table 4.1: Projected populations (2017-2037)

Description	Unit	Year					
		2017	2018	2022	2027	2032	2037
Urban Growth Rate	%	4.20	4.20	4.00	3.80	3.60	3.20
Population	No.	244871	255375	299685	362394	433864	509144

Based on the above table 4.1 the population of the Sebeta is 244,871 (2017) and 509,144 (2037).

4.1.2 Average Daily per capital Consumption

The level of water consumed for domestic purpose has been aggregated to town so as to analysis the distribution of the water coverage among different localities. Evaluating the domestic water supply coverage using volume of consumption may not allow realizing the distribution comparison among the town. For this reason the annual consumption data has been converted to average daily per capital consumption using the number of population.

Table 4.2: Water production and consumption of Sebeta

Year	Production m^3/year	Consumption m^3/year	Water loss m^3/year	Percentage of water loss	Total population	Consumption l/person/day
2017	2640453	1787148	853305	32.3	244871	20.85

As shown on the Table 4.2 the distribution of average domestic water supply coverage of the town in the year 2017 is found to be 20 liter/capita/day. This average per capita consumption is very low while compared with country standard used for design purpose (30 to 60 l/capita/day) as per EBCS 9. According to some literatures, a minimum quantity of 25 l/capita/day domestic water supply categorized as basic level of service (Wallingford HR, 2003) which is higher than the average domestic consumption of the town.

4.1.3 Average water demand

The most common means of forecasting future water demand is estimating current per capita water consumption and multiplying it by the projected population figure. Thus, the average water demand for Sebeta town was calculated to be 4,897,420 l/day.

4.1.4 Population Distribution by Mode of Service

Mode of service is an important element on the one hand for evaluating the level of water coverage that was the focus of this section and on the other hand it has a direct impact on the water loss that was dealt separately.

The adopted per capita water demands of each of the modes of services are described in the table below. It was the result obtained from the demand analysis.

Table 4.3: Population percentage distribution by mode of service

User	Total Number of Population served	Percentage
Public Tap (PTU)	180519	73.73
YTU (private)	60655	24.77
House Connection	3673	1.5
Total	244847	100

As shown in the table 4.3 above the demand analysis identified the households who have access to safe water supply by mode of services. The demand analysis indicates that, the majority of the inhabitants (about 73.73 %) get their water from a tap outside their compound (i.e. from public fountains and vendors). About 24.77 % have a private yard connection and 1.5 % has house connection.

4.1.5 Evaluating of the Distribution of the Water Supply Coverage

Here the distribution of the consumption in relation to number of population is discussed. In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound. According to the information obtained from the survey, the water provided by the office is unable to cover the current growing demand of the town. The other problem observed with urban water supply system is that the pipe line distribution system is not orderly aligned in most cases, and this may result in big loss of water. Therefore, the distribution system needs improvement. The problems are because of the fast expansion of the town, population growth, the expansion of different NGO's factories have increased the demand of water.

4.1.6 The status of existing water supply in Sebeta town

The scheme serves the population of Sebeta town and the source of water for the existing water supply system is underground water. Water is stored in the reservoir by the power of pumps and is distributed by gravity during high consumption hours of the day.

The town water supply has been started to serve the population of Sebeta town and the surrounding village but, it faced some difficulties to transport the water from the source to the users because during the hot season the water decreased from the sources. These create problem to store the water in the reservoir during the day time. So that by storing the water during the night time and distributed to the community at the day time.

The annual water production is about 2640453 meter cube in 2017. This amount of water does not fulfill demand of community in urban areas and the people are forced to fetch water from river by using animals or getting water from private sellers. It exposed the community for different problems like unwanted or unplanned expenses and health problem. Due to shortage of water from the source the daily question of the community did not get answer. Additionally expansion of the town, population growth, and the expansion of different factories around the town increased demand of water. Moreover, continuous break down of pipe lines because of their long time services aggravated the problem of urban water users.

4.3 Distribution System Modeling

4.3.1 Model Representation

Frequently system maps are drawn as combination of various system components enclosed in water distribution system. It is common to include: Reservoirs, Tanks, Pipes and Pumps as much as possible and the resulting sketch fairly represent the actual water network. With little difference the real water distribution system represented as combination of nodes and links. Junctions, reservoirs, and tanks are usually referred as nodes. Pumps and pipes are referred as links. Figure 4.1 below illustrates layout of Sebeta distribution system.

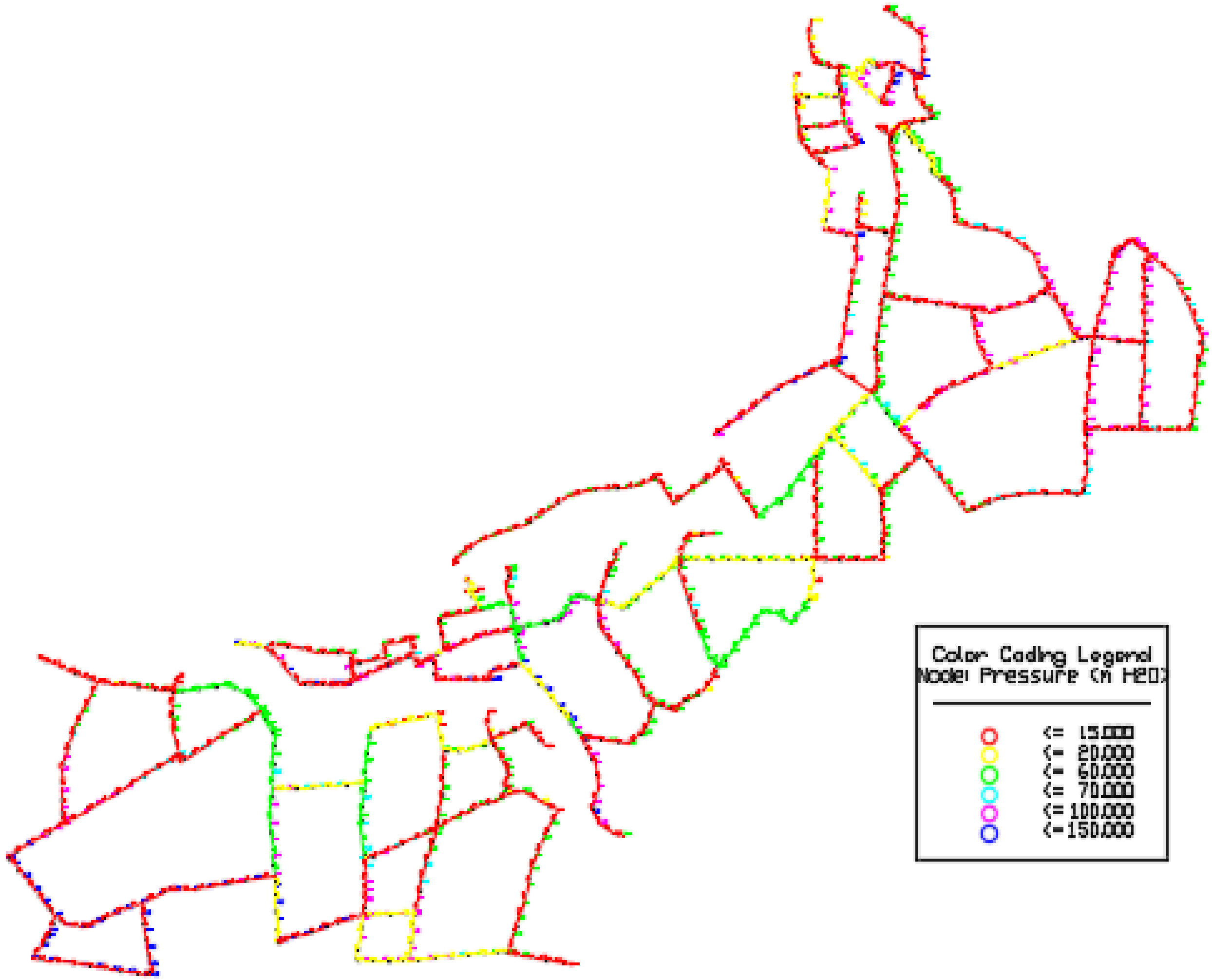


Figure 4. 1: Layout of Sebeta supply system

From the above figure which was done by using water CAD modeling, the summary of the elements found in the system is shown in the table below.

Table 4.4: Summary of system elements

System Components	Number
Junctions	697
Pipes	115km and 886m.
Pumps	28
Service Reservoirs (Tanks)	4

4.4 Simulation Results

Single period and extended period simulation were subsequently performed. It was required to run single period simulation at the beginning of the simulation as to observe the model under snap shot situation. In line with this, running single period simulation was helpful while performing preliminary model calibration. However, it should not be used for network assessment as water distribution system is likely to experience variations. Hence, only extended period simulation was exclusively used for entire model calibration and model assessment effort. Demand patterns used in simulating extended period simulation is presented in Appendix F.

4.4.1 Pressure

Pressure in water distribution system has to be maintained optimum; as to efficiently make water available to each demand category including at instance of firefighting (high withdrawal period) and as to reduce leakage as well as pipe breakage across the system. The former one is frequently achieved in setting minimum pressure to be maintained at each junction. The later one is achieved differently in setting maximum allowable pressure to be maintained in the system.

Accordingly to Swamee and et al., (2008) the minimum design nodal pressures are prescribed to discharge design flows onto the properties. It is based on population served, type of dwellings in the area, and firefighting requirements. The general consideration is that the water should reach up to the upper stories of low-rise buildings in sufficient quality and pressure, considering firefighting requirements. In case of high-rise buildings, booster pumps are installed in the water supply system to cater for the pressure head requirements.

Similarly, Johnson and et al., (2009) recommend;

1. Minimum pressure at peak hour demand: sufficient to serve the highest supply point in the network. Typically a mains pressure of not less than 15 to 20 m would be required to serve buildings up to three storeys high. High pressures may be necessary in some areas where there are significant numbers of dwellings exceeding three storey height; but high rise buildings are normally required to have their own boosted supply.

2. Maximum static pressures during low demand periods: typically at night should be as low as practicable to minimize leakage. For flat areas a maximum static pressure in the range 30 to 45 m is desirable.

For Sebeta town, an operating pressure which ranges from 15m to 70m was used. With regard to current simulation, result for pressure at peak flow is summarized Table 4.5 and detailed in Appendix G

Table 4.5: Distribution of pressure at peak hour flow

Pressure	Nodes (Number)	Percentage (%)
>70	155.00	22.24
60-70	48.00	6.9
50-60	103	14.78
40-50	76.00	10.9
30-40	62.00	8.9
20-30	73.00	10.47
15-20	43.00	6.17
<15	137.00	19.66

As depicted in Table 4.5, 19.66% of nodes are failed to satisfy minimum pressure requirements during peak hour flow. And 22.24% of nodes exceed maximum allowable pressure of 70m. Finally, 58.11% of nodes are in the permissible pressure range of minimum 15m and maximum 70m.

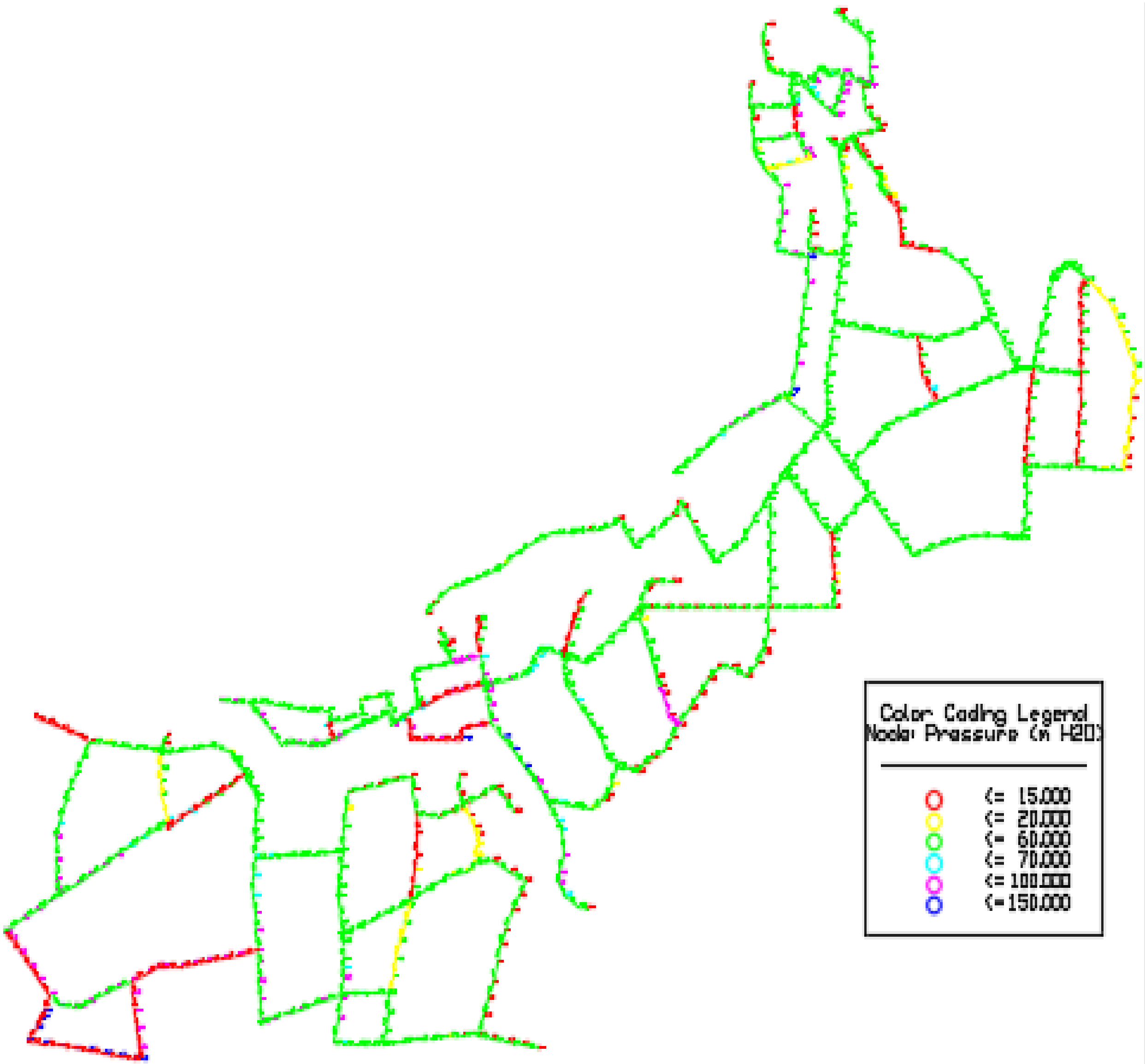


Figure 4. 2: Pressure distribution plot of peak hour flow

Figure 4.2 shows pressure profile during peak hour flow. As shown in the Figure 4.2, nodes located near to tanks and wells as well as few nodes located at remote area are susceptible to excessive pressure which exceeds allowable maximum pressure.

In contrary minimum pressures are also observed mainly nodes situated near to tanks. In few instances nodes positioned in middle of network are susceptible to low pressure. Whereas majority of nodes located in relative perfect loop region receive optimum pressure which doesn't violet minimum or maximum allowable pressure range.

Table 4.6: Pressure distribution during low flow

Pressure	Nodes (Number)	Percentage (%)
>70	275	39.46
60-70	75	10.76
50-60	58	8.32
40-50	74	10.62
30-40	72	10.33
20-30	58	8.32
15-20	37	5.31
<15	48	6.89

During low flow typically at mid-night distribution system of case study is marked by excessive pressure. As portrayed in Table 4.6 and detailed in Appendix H, 39.46% of nodes are liable to extremely high pressure. This figure is relatively high. Only 53.66% of nodes are obtaining water of optimum pressure. Finally, 6.89% of nodes are failed to satisfy minimum pressure requirements during low flow.

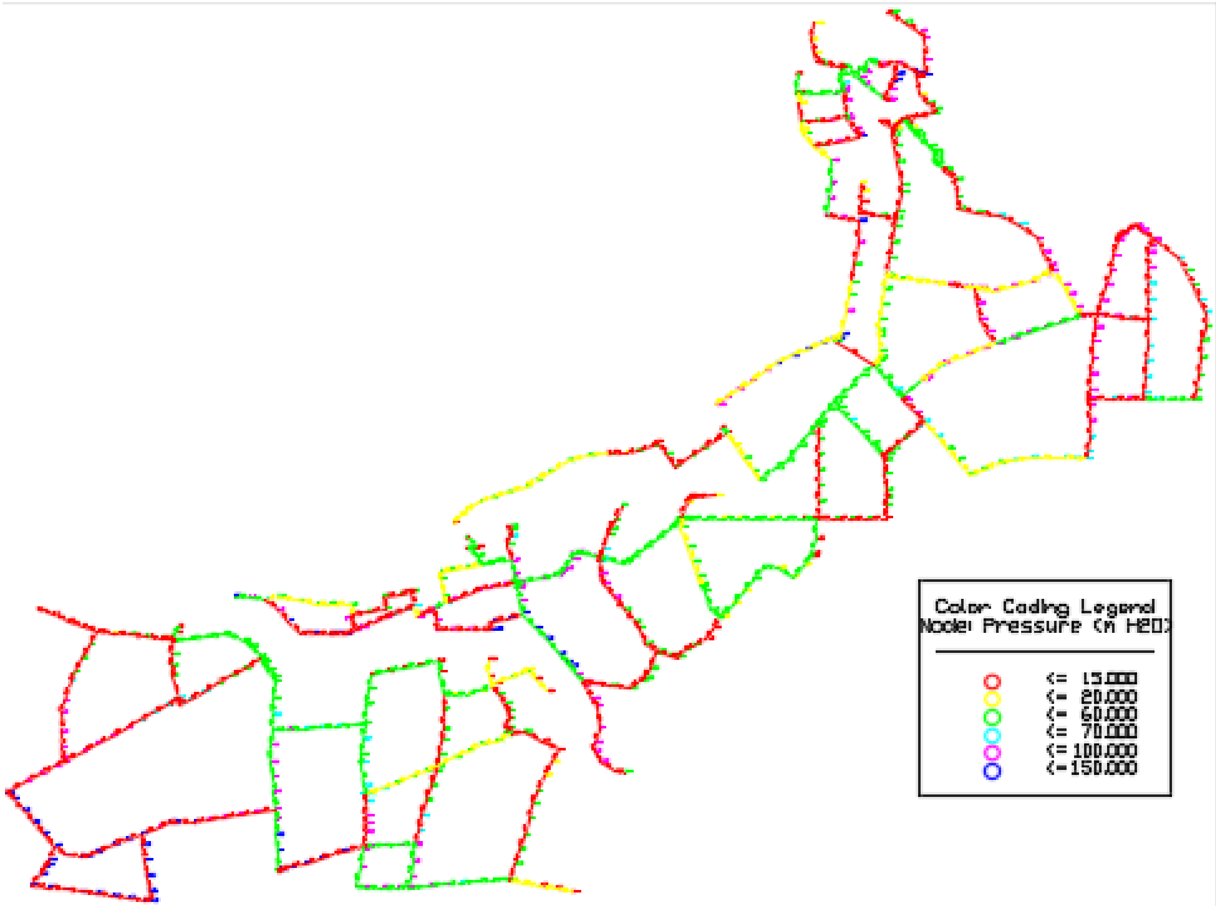


Figure 4. 3: Pressure distribution plot during low flow

As shown in figure 4.3, those colored blue are nodes exposed to high pressure (twice allowable maximum pressure). Those colored red are also failed to satisfy permissible minimum pressure.

4.5 Model Calibration and Validation

The credibility of a model is merely evident if a model result precisely reflects observed field values. Thus, to have a confidence on model result it is required to calibrate and validate a model. An effort to perform hydraulic model calibration and validation for this case study is presented as follows.

4.5.1 Hydraulic Model Calibration and Validation

For assuring the entered water distribution model inputs data accuracy; the computed model results have been compared with the actual observed field conditions of study area. The sets of data collected for hydraulic model calibration and validation were attached in Appendix I and

Figure 4.4 and Figure 4.5 illustrate plots of observed vs computed values along with minimum and maximum difference between them.

From these two figures, by comparing the measured value with the computed value, the gabs were recorded up to 54m head. This value was out of the pressure standard and limitation suggested by Tomas, et al., (2003). Therefore, the computed pressure value of both peak demand and low demand were calibrated until the result was approach to the measured value.

During the pressure measurement on site, the pictures were attached in appendix O and P.

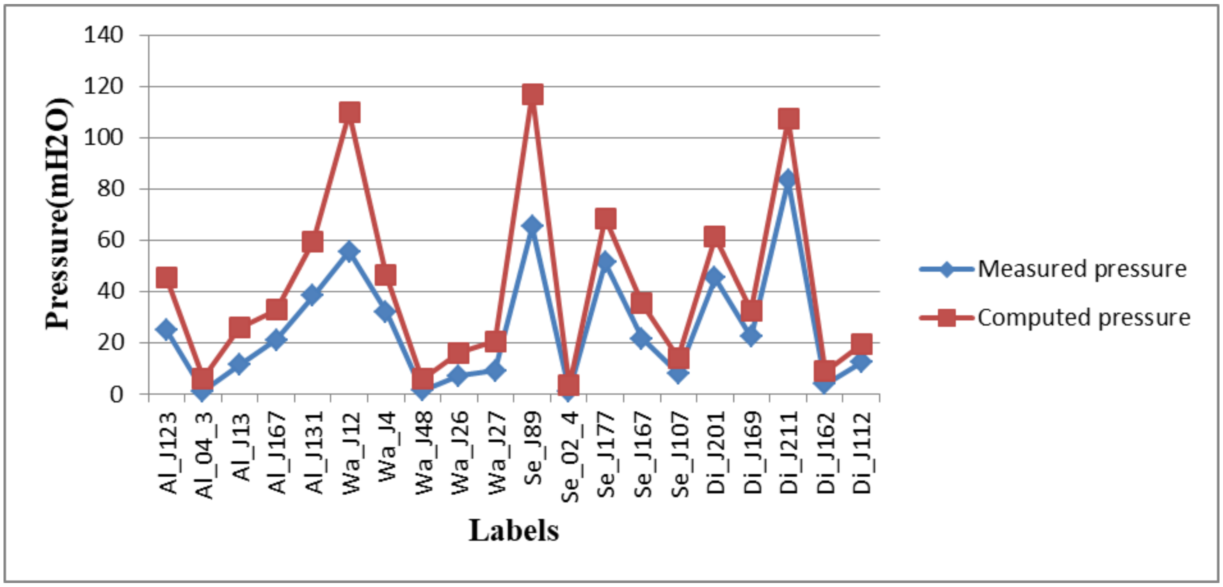


Figure 4. 4: Computed and Measured pressure value during peak demand time

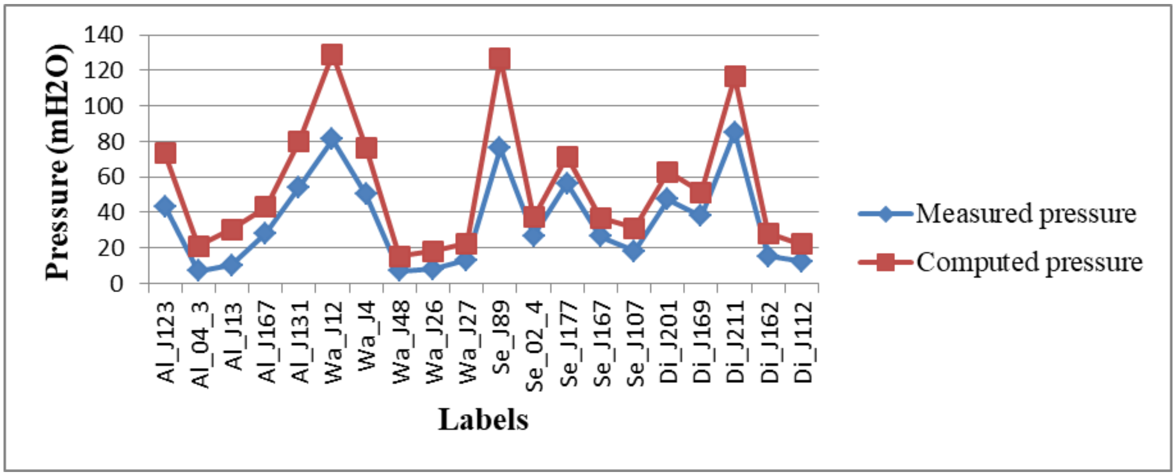


Figure 4. 5: Computed and Measured pressure value during low demand time

As per pressure criteria, 85% of the computed model results should become within ±0.5m head of the measured value. Therefore, to assure the acceptable level of calibration, the input parameters were adjusted.

4.5.2 Model Validation

The model validation work was taken by comparing the measured pressure and computed values. The correlation was used to check that the model was validated. The measured pressure is attached in Appendix J. The correlation coefficient equation (R^2) method represent graphically in figure.

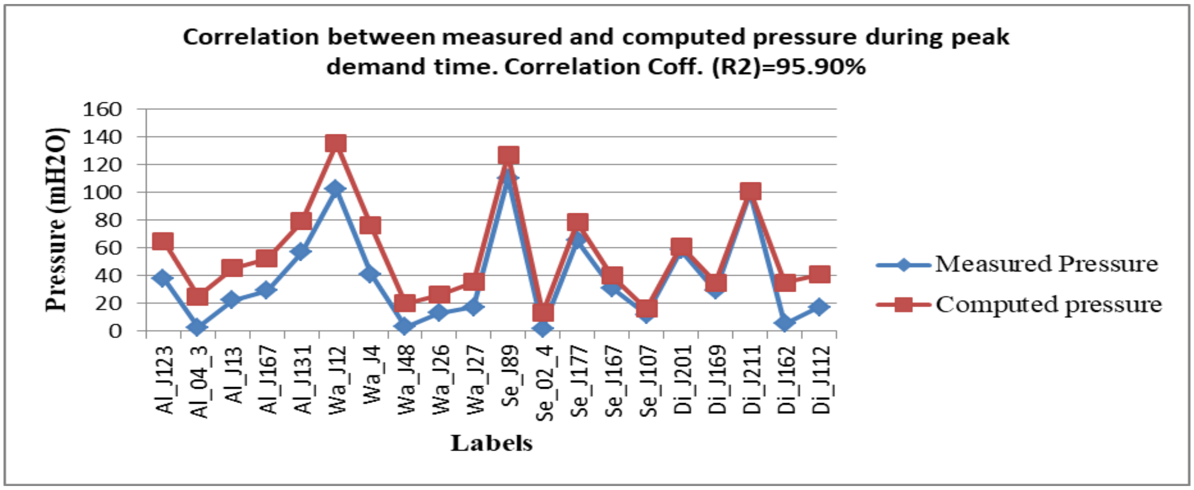


Figure 4.6: Correlated plot during pressure calibration for peak demand time

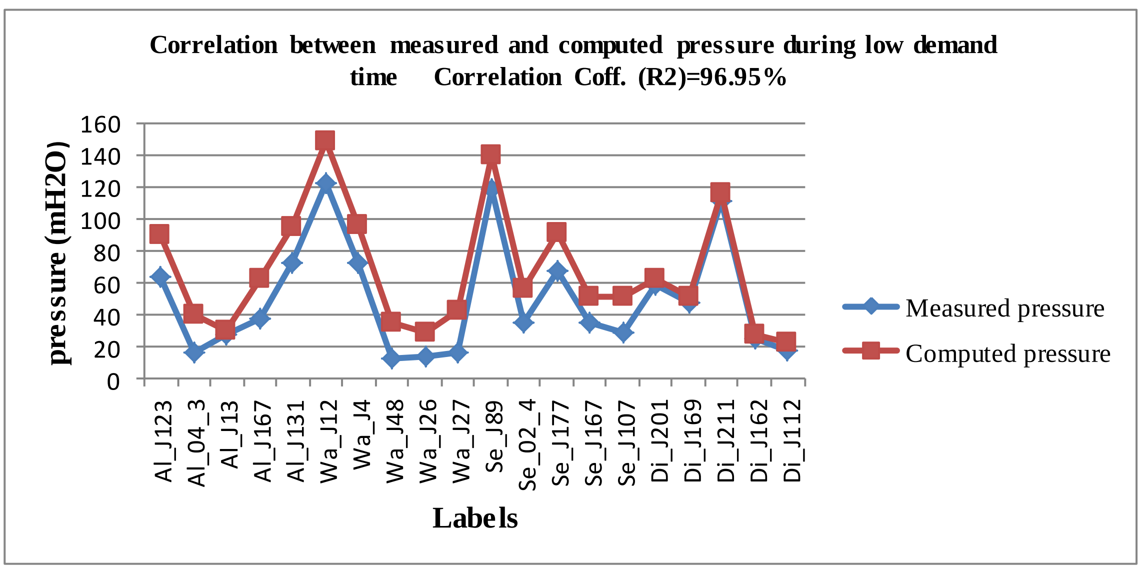


Figure 4.7: Correlated plot during pressure calibration for low demand time

From Figure 4.6 and 4.7, it explains that the results of correlation value (R^2) for both scenario; peak and low demand time was represent as 0.9590 and 0.9695, respectively. Therefore, the calibration pressure value was validated within the recommended standard.

4.6 Water quality analysis

4.6.1 Physicochemical Parameters

PH, Total Dissolved Solid, Total Hardness and Chloride

The PH

PH levels closer to 8 are more suitable for effective operation in water treatment plants, while values less than 7 can lead to corrosion of distribution pipe materials (WHO, 2011). Data in table 4.7 shows that the PH of water obtained from these six sources, varied from PH 6.70 to 7.63. Sebeta public fountain had the lowest PH value, followed by Dima public fountain (PH 6.75), Alemgena household (7.2mg/l), Walate household (7.35mg/l), Sebeta household tap (PH 7.41) and Dima household tap (PH 7.63) being the highest. The PH values of all sources were within the WHO acceptable guideline value of 6.5 to 8.5. Water sample with low PH attributed to discharge of acidic water into these sources by agricultural and domestic activities. Sample collected from Sebeta water tap and Dima household tap were slightly basic which can be seen from its PH and alkalinity values. Though PH has no direct effect on the human health, all the biochemical reactions are sensitive to variation of PH. For most reactions as well as for human beings PH value 7.0 is considered as the best and ideal. In the present study, PH value of water samples varied in a narrow permissible limit in all sources.

Total Dissolved Solid

Dissolved solids are often composed of inorganic salts and organic matter, are usually tolerated up to 600 mg/l but are unacceptable at levels greater than 1000 mg/l (WHO, 2011). Higher levels of TDS often alter the taste of water and cause dissatisfaction by the water consumers. Form Table 4.8 all the six sources of water had levels of TDS content which met the WHO guideline standard value of 1000 mg/l. The mean TDS content values ranged from 398 to 481 mg/l. Dima public fountain had the lowest TDS value of 398 mg/l, followed by Walate household (401mg/l), Sebeta household tap (450 mg/l), Sebeta public fountain (453 mg/l), Alemgena household

(461mg/l) and the highest level was observed in Dima household tap (481 mg/l). Generally, from this result we can understand that the absence of underground salt stores that alter the taste of water.

Total Hardness

Water hardness in this study varied with values ranging from 156 to 228.6 mg/l (Table 4.4.1). These values were, however, within WHO maximum contaminant value of 500 mg/l. Hardness positively correlated with Ca^{2+} and Mg^{2+} concentrations. This shows that factors that may have contributed to Ca^{2+} and Mg^{2+} concentrations may directly affect hardness values.

According to Thomas (1953), the degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration as follows:

Soft; 0 to < 60 mg/l; Medium Hard: 60 to 120 mg/l; and Hard 120 mg/l and above.

Based on the above classification, all the water samples were hard water. Soft water lathers well with soap whereas hard water does not.

Chloride Ions, Cl^-

Chloride is a naturally occurring compound found in groundwater supplies and causes a salty taste, often at levels greater than 250 mg/l. Results in Table 4.7 show that, the Cl^- concentration in all the six sources of drinking tested were within the WHO guideline acceptable value of 250 mg/l. The Cl^- concentration for all the six sources varied between 7.4 to 14.4 mg/l.

Table 4.7: Result of physic-chemical parameters

Water Sources	**Physico-Chemical Parameters**			
	PH (mg/l)	Total Dissolved Solid (mg/l)	Total Hardness (mg/l)	Chloride (mg/l)
Sebeta Household tap	7.41	450	163.4	7.4
Dima Household tap	7.63	481	156	8.4
Sebeta PF	6.7	453	163.2	14.4
Dima PF	6.75	398	146.8	11.4
Alemgena household	7.2	461	228.6	10.6

Walate household	7.35	401	215	9.5

Fluoride, Total alkalinity, Total Suspended Solid and Turbidity

Fluoride Ion, F^-

Drinking water from the various sampling points were characterized by low fluoride ion concentrations and fell within WHO acceptable limits of drinking and potable water of 1.5 mg/l. The concentrations ranged from 0.32 to 0.66 mg/l (Table 4.8). The F^- concentrations in these waters however, might be due to fluoride containing minerals. The relatively low concentrations could be explained that the various sampling points were not rich in fluoride-containing minerals. This also indicated that there is no evidence of industrial pollutions.

Concentrations above 1.5 mg/l carry an increasing risk of dental fluorosis, and much higher concentrations lead to skeletal fluorosis.

Total Alkalinity

Table 4.8, shows that the lowest value for total alkalinity was found in Sebeta public fountain (121.2 mg/l), followed by Dima public fountain (158.8 mg/l), Alemgena household (160.3 mg/l)Sebeta Household tap (163.4 mg/l), Walate household (169.71 mg/l) and The highest level was found in Dima Household tap (179.6 mg/l). Total alkalinity, however, ranged from 121.2 to 179.6 mg/l.

Total Suspended Solid (TSS)

All water samples under the study, recorded low TSS value less than 0.0001 (Table 4.9). TSS was found to be lowest in all water samples. This indicate that the probability of groundwater affected by flooding, effluent, discharge and infiltration is less than surface water and shallow wells. Surface water and shallow wells have been known to be affected by flooding, effluent, discharge and infiltration Nduka et al., (2008).

The greater the amount of total suspended solids, the murkier it appears and the higher the measured turbidity. TSS is an indication of the amount of erosion that took place. (http://www.duluthstreams.org).

Turbidity

All water samples had their levels of turbidity within the limit of acceptable standard of drinking water of 5 NTU according to WHO (2011). The recorded value for all samples was < 0.0001. This is the lowest value compared to 5 NTU values which indicate that the possibility of the system to be contaminated by the soil particles and other particles is very low.

The occurrence of turbidity of surface water may be permanent or seasonal. These high turbidity values affected the clarity of the water and reduce the depth to which light could penetrate. Turbidity has also been long known to hinder disinfection by shielding microbes, some of them perhaps pathogens.

Table 4.8: Result of physic-chemical parameters

Water Sources	**Physico-Chemical Parameters**			
	F^- (mg/l)	Total Alkalinity (mg/l)	TSS (mg/l)	Turbidity (NTU)
Sebeta Household tap	0.66	163.4	<0.0001	<0.0001
Dima Household tap	0.66	179.6	<0.0001	<0.0001
Sebeta PF	0.59	121.2	<0.0001	<0.0001
Ayka PF	0.35	158.8	<0.0001	<0.0001
Alemgena household	0.32	160.3	<0.0001	<0.0001
Walate household	0.37	169.71	<0.0001	<0.0001

4.6.2 Microbiological Parameters

Total Coliform

As shown in table 4.9 the total coliform for all samples is much departed from WHO standards. This shows that the drinking water sources can be contaminated by storm water run-off from roadways, farms and livestock operations, and discharges from sewage treatment or septic systems. The presence of coliform bacteria in water does not guarantee that drinking the water will cause an illness. Rather their presence indicates that a contamination pathway exist between a source of bacteria (surface water, septic system, animal waste, etc) and the water supply.

Disease causing bacteria may use this pathway to enter the water supply. Since coliform bacteria usually present in water longer than most disease-causing organisms, the absence of coliform bacteria leads to the assumption that the water supply is microbiologically safe to drink. All the physicochemical and Biological parameters results attached in appendix S.

Table 4.9: total coliform for all samples

S. N	Parameter	Sebeta Household tap	Dima Household tap	Sebeta PF	Dima PF	Alemgena Househol d tap	Walate Household tap
1	Total coliform	2060/100ml	1853/100ml	1470/100 ml	841/100ml	6712/100 ml	575/100ml

4.7 House hold survey regarding the availability, water tariff and consumption of water

This part of study deals with the presentation, analysis and interpretation of data collected from study area and the respondents through questionnaires and interview.

Table 4.10 indicates the response of respondents upon their satisfaction on the water delivery.

Table 4.10**:** Satisfaction level of water supply service of Sebeta town based on house hold

S.N	Existing water supply	Number of respondents	Percentage of respondents
1	Very satisfactory	12	3.15
2	Satisfactory	28	7.4
3	Unsatisfactory	334	87.66
4	Non-respondents	7	1.8
Total		381	100

Source: Field survey, 2017

Distance to get water

Distance is one of the determining factors to affect accessiblity of water both in rural and urban area. It means that when they are travelling more and more distance they exposed for more economic problems like additional cost to travel the water and wastage of time. According to standard set by water and energy ministry of Ethiopia allow rural communities to get 15 liters of water within a radius of 1.5 km and urban areas 20 liters within 0.5 km. But, the result obtained from the observation disproved the standard set by water and energy minister of Ethiopia. Table 4.11 indicates the distance of water from the source in the study area.

Table 4.11: Distance of water from the source

S.N	Distance from the source	Frequency	Percentage
1	<1 km	52	13.67
2	1-2 km	148	38.85
3	3-4 km	76	19.95
4	4-5 km	59	15.49
5	>5 km	46	12.07
	Total	381	100

Source: Field Survey, 2017

As indicated in Table 4.11, many of household travelling nearly more than one kilometer to get water. When they were asked of the average distance travelled to fetch water 12.07 percent said they travelled greater than 5 km, 19.95 percent travelled between 3 to 4 km, 15.49 percent travelled between 4 to 5 km, whilst 38.85 percent travelled between 1 to 2 km before fetching water for their households, 13.67 percent travelled less than 1 km.

The result obtained from the sample respondents indicate that majority of them are travelling more distance and waste time, this implies that location of water sources and its distance from home affects household per capita water consumption. Households who are fetching water from long distances spend much of their time, which could have been used for other purposes and affect the economic performance of the community.

Table 4.12: Purposes of household consumption

S.N	Types of consumption	Frequency	Percentage
1	Drinking & cooking	182	47.77
2	Washing clothes	76	19.95
3	Bathing	71	18.64
4	Other purpose (Gardening, Cleaning vehicles, animals etc.)	52	13.65
Total		381	100

Source: Survey Data, 2017

From the table 4.12 above it can be observed that households are using water for different functions. Out of the total house holds 47.77 percent of sample households use water for drinking and cooking and 19.95 percent for washing clothes. The rest 18.64 and 13.65 percent are covered by bathing and other purpose respectively.

The high water consumption in hot season is caused by increased bathing, washing clothes and drinking more water than in cold season. In addition to this in the hot season of Sebeta, the dusty wind which comes from different direction with high amount of dust and soil particle is increasing and become a great challenge for each house hold in the town. Thus, people in the study area need more water for bathing and washing clothes because of its dusty nature of the surrounding town.

In relation to the above discussions respondents were asked for about the adequecy of water which was delivered to their house hold. From these respondents, 4.1 percent of them reported very good, 4.9 percent responded good, 5.3 percent satisfactory and 85.7 percent reported poor. This implies more than three-fourth of the respondents had no adequete water for their daily consumption and are not satisfied whith the water supply of the town. Figure 4.8 depicts the adequecy of water.

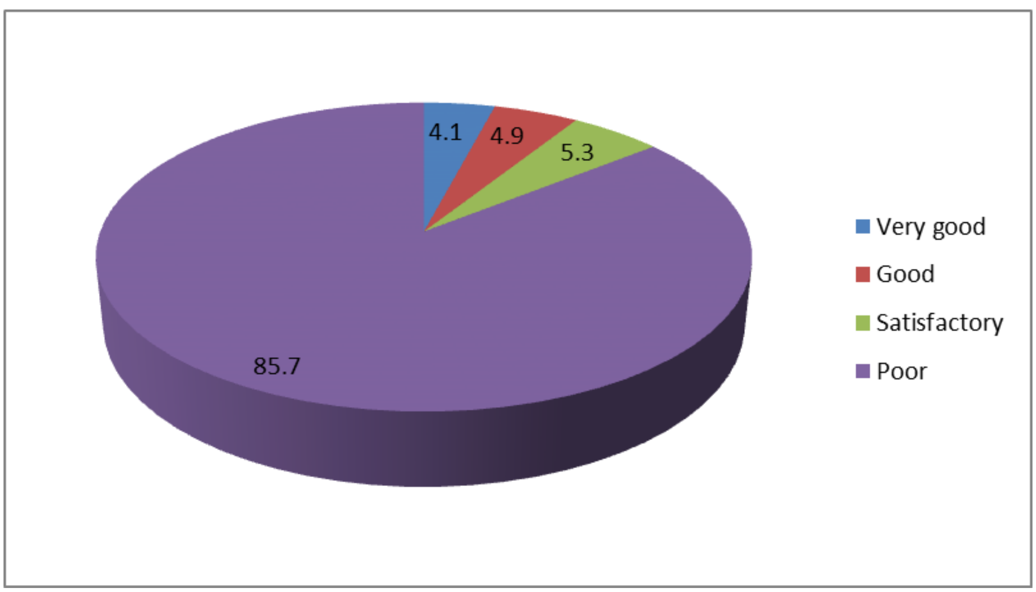


Figure 4.8: Adequecy of water for household

Source: Field Survey, 2017

Frequency of interruption

In Sebeta town, water supply is interrupted repeatedly because of different reasons. Power failures can cause complete interruption in the water supply system and then less consumption. As the seasonal temperature varies greatly in the region, power consumption rate of Sebeta town greatly fluctuates between seasons. The consumption is low during relatively cold season and high consumption is registered during the hot season. This may be because of high demand of power for refrigerator, ventilator and other devices in the hot season of the area. Thus, water is unable to store in the reservoirs because of this interruption of electric power repeatedly. In addition to this there are also other factors mentioned as a reason for water interruption in Sebeta town. These includes continuous breakdown of pipe lines by illegal house construction in the town due to the unplanned or uncoordinated plan of activities of the municipality.

In similar way, the other factors which affect the supply of water are the precence of very old pipe lines, shortage of stand by generators when there is unexpected power interruption and the shortage of spare parts. When such complete interruption occurs, the housesholds faced different challenge.

Table 4.13**:** The condition of interruption in the study area.

S.N	Condition of water interruption	No. of private users	%	No. of public users	%
1	Once in a week	117	30.71	147	38.58
2	Twice in a week	91	23.89	84	22.05
3	Three times in a week	73	19.16	67	17.59
4	Four times in a week	67	17.59	52	13.65
5	Five times in a week	20	5.25	21	5.51
6	Six times in a week	10	2.63	7	1.84
7	Seven times in a week	3	0.79	3	0.79
	Total	381	100	381	100

As indicated in Table 4.13 the frequency of interruption occurs more seasonally (varying between bega and kiremt) but the situation is better in summer season due to more availability of water from its sources. Among the total private pipe water users 30.71 percent of the respondents have access to pipe water once in a weeks, 23.89 percent twice in a week, 19.16 percent gets water three times in a week, 17.59 percent gets water four times in a week, 5.25 gets water five times in a week. And the rest 2.63 and 0.79 percent of the respondents have access to pipe water six and seven times in a week respectively.

Among the public users 38.58 percents are get water once in a week, 22.05 percent two times in a week, 17.59 percent three times in a week, 13.65 percent four times in a week, 5.51 percent are get water five times in a week and 1.84 percent six times in a week. Finally, 0.78 percent are get water seven times. People wait for too long at the source for turn to fetch water. More than 50% of people in Sebeta town wait nearly 3 hour before they can fetch water because the particular time of water flow is not known during the days.

For this reason people have to wake up so early in the morning and queue with their jerican for water from any public tab nearest to them, then get back to their home to wait whilst doing other things.

Water Tariff Setting

Water use practices and willingness to pay for water services in urban areas depend highly on household income.

The existing water tariff structure applied by Sebeta town water service has four grades rising gradually from birr 4.50 for the lowest consumption grade of 0-3m^3 to birr 6.10 for the highest grade of over 10m^3. The tariff for public tab users is birr 3.50/m^3. The breakdown of the existing operational tariff rate is shown in the table below:

Table 4.14: Current water tariff rate of Sebeta town

Mode of service	Consumption range and tariff proposed for the implementation	
	Consumption range, m^3/month	Tariff proposed, birr/m^3
Public tab	M^3	3.50
Service connection	Block one, 0-3m^3	4.50
	Block one, 4-7m^3	5.00
	Block one, 8-10m^3	5.50
	>10m^3	6.10

(Source: STWSSO)

The amount that households pay for a 20 liters or 1 jerican of water varies from place to place and season to season depending on the level of scarcity of water and the demand for water by the people from a particular owner of a reservoir or a big tanker or venders. The difference in price indicates that communities are taking water from different sources based of their income, short distance to the water source and water avalabilty. The difference in water source makes difference in water price.

Table 4. 15: Cost of water per jerican

S.N	Water cost per jerican/20 liters	Frequency	Percentage
1	>5 birr	102	26.77
2	4-5 birr	85	22.31
3	3-4 birr	75	19.69
4	2-3 birr	48	12.6
5	1-2 birr	41	10.76
6	1 birr	20	5.25
7	Non-respondents	10	2.63
	Total	381	100

Source: Field Survey, 2017

Table 4. 16: Respondents' comments on the existing water tariff.

S.N	Responses	Frequency	Percentage
1	Cheap	42	11.02
2	Fair	48	12.6
3	Expensive	111	29.13
4	Very expensive	160	42
5	Non-respondents	20	5.25
	Total	381	100

Source: Field Survey, 2017

According to the result of survey, the sampled HHs had given their comments on the water price of Sebeta town. Out of the total sampled households 42 percent commented the price set is very expensive especially for private pipe connections. Other 29.13 percent commented the price is expensive. Other 12.6 percent commented the price as fair may be for those who pay less when they consume more. 11.02 percent reported that the price was cheap and the remaining 5.25 percent are non-respondent.

CHAPTER FIVE

5.CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

- The inhabitants living in the town are facing serious water shortage problems, especially people living in expansion area of the town and town part located at higher altitudes than existing service reservoir sites are fetching water from venders at an exorbitant cost than the normal water tariff set by the town water supply office. The water tariff set by STWSSO and the board of Sebeta town water supply for private connection and its connection charges was unfair to the poor segments of the community. This is because of the fact that those who consume more volume of water pay low price due to the price set in this manner and also the high connection charges. This implies that the tariff subsidizes the urban rich, as they are the one that could afford and consume more than the poor and could also sold from their private meter for the poor at higher price than the price they paid for WSS office.
- According to the information obtained from the survey, the water provided by the office is unable to cover the current growing demand of the town. Therefore, the demand and supply system was unbalanced.
- The base of the assessment was evaluating hydraulic performance of the distribution system as well as analyzing issues of water pressure in the distribution system based on results of calibrated and validated model. With intended objective the study was undertaken and it has come with significant outcome.
- Pressure based hydraulic perfomance evaluation indicated that acceptable minimum and maximum pressure have not met. During peak hour flow, parts of the distribution system receive water with low pressure and under some circumstances risk of obtaining no water is observed because of the pressure in the distribution system is beyond permissible minimum requirement. In line with this, about one third of the distribution system is prone to undedesirable pressures which exceed maximum allowable pressure. As result, the

distribution system is exposed to risks of high leakage and repeated pipe breakage during low flows.

- Along with this, hydraulic modeling results revealed the existence of both design and operational problems. Observed pressures which exceed maximum allowable pressure even during peak hour flow and observed pressures which is lower than minimum allowable pressure during low flow hours clearly proved pressures the existence of desgn problems. While generated excessive pressures clearly proved the existence of operational problems.
- In general, the simulated hydraulic result indicated that the current hydraulic performance of Sebeta supply system is not efficient. But it doesn'n mean that the subsystem is not functional. Rather the frequency of service interruption is relatively high. This interruption is partly contributing for the current water shortage in the town.
- The water quality tets result shows that, it is not as guideline of the WHO standards as some parameters depart from these guidelines.
- Generally, the existing water supply systems to the Sebeta town do not satisfy the water requirement in availabilty, distribution, consumption, quality and quantity for these tremendously increasing populations of the town.

5.2 RECOMMENDATION

After evaluating the supply and demand of the study area and to improve the current situation of Sebeta supply system, both design and operational modifications are necessary. From the study undertaken and modeling result the following set of recommendatins are drawn:

- New water sources need to be developed to satisfy the gap between existing supply and demand.
- The proposed water supply system has been thoroughly analyzed, designed and all components have been optimized and selected to obtain the most economical and best performing scheme.
- To permanently modify the hydraulic performance of the sub system, the design needs to be reviewed and pressure zones which serve customers situated in nearly equivalent elevation has to be established.
- The Sebeta town network lay out system must be reviewed and the pipe diameters re-fixed based on the flow, pressure and velocity.
- Adjustment or implementation of pressure reducing valve or break pressure tanks; devices which decrease pressure are recommended as to control the occurrences of maximum pressures for isolated parts of network.
- Uses of pressure sustaining valves are recommended as to control the occurrences of minimum pressures. These valves start closing if the upstream pressure falls below the present value as to guarantee allowable minimum pressure for isolated parts of network.
- Water meters should be installed at all sources, reservoirs and collection chambers inlet and outlet pipes and proper water production recording should be in place.
- It is recommended that microbiological and physicochemical water quality test must be conducted priodically to check weather it fulfils standards of the WHO guidelines or not.
- All relevant documents, feasibility studies, borehole history, manufacturer manuals and detail designs, as built drawings of all existing water supply system components(sources, collection chambers, reservoirs, etc) need to be documented in a well organized way and should be available in the water utility office for future reference.

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APPENDIX

Appendix A

Source and discharge points of Boreholes in Sebeta town

No.	Site name	Location	Code	Geographic Location			Deliver to Reservoir
				Easting	Northing	Elevation	
1	Geme well field	Geme	GBH1	456718	983056	2117	SR
2	Geme well field	Geme	GBH2	456535	982758	2105	
3	Geme well field	Geme	GBH3	456468	981994	2087	
4	Geme well field	Geme	GBH4	456566	981216	2078	
5	Geme well field	Geme	GBH5	455999	981290	2078	DR
6	Geme well field	Geme	GBH6	455530	981389	2081	
7	Geme well field	Geme	GBH7	454876	981290	2083	
8	Geme well field	Geme	GBH8	454624	980812	2073	
9	Geme well field	Geme	GBH9	454703	981809	2088	
10	Geme well field	Geme	GBH10	455422	982340	2093	
11	Geme well field	Geme	GBH11	455376	983046	2108	
12	Furi well field	Furi	FBH9	464628	990283	2279	WR
13	Furi well field	Furi	FBH10	464856	989853	2271	
14	Furi well field	Furi	FBH11	464993	989321	2264	
15	Furi well field	Furi	FBH12	465046	988789	2260	
16	Alemgena well field	Alemgena	ABH-1	460095	984923	2212	AR
17	Alemgena well field	Alemgena	ABH-2	459776	984528	2193	
18	Alemgena well field	Alemgena	ABH-3	459252	984391	2169	
19	Alemgena well field	Alemgena	ABH-4	458925	983616	2146	
20	Furi well field	Furi	FBH1	466031	987338	2253	
21	Furi well field	Furi	FBH2	466064	987696	2253	
22	Furi well field	Furi	FBH3	466046	988063	2248	
23	Furi well field	Furi	FBH4	465727	988069	2250	
24	Furi well field	Furi	FBH5	465348	988079	2256	
25	Furi well field	Furi	FBH6	464723	987715	2255	
26	Furi well field	Furi	FBH7	464867	988193	2259	
27	Furi well field	Furi	FBH8	463400	987342	2276	

Appendix B

Pipe inventory for Dima subsystem

Diameter (mm)	Material	Pipe Class	Total Length (m)
50	HDPE	PN16	92
80	uPVC	PN10	2,912
80	uPVC	PN16	3,696
100	uPVC	PN10	3,564
100	uPVC	PN16	1,701
150	uPVC	PN10	5,127
150	uPVC	PN16	3,242
200	uPVC	PN10	2,942
200	uPVC	PN16	1,248
250	uPVC	PN10	1,758
250	uPVC	PN16	1,891
300	uPVC	PN10	1,746
400	DCI	PN10	2,929
500	DCI	PN10	427
		Total Length	**33,270 m**

Appendix C

Pipe Inventory for Sebeta subsystem

Diameter (mm)	Material	Pipe Class	Total Length (m)
50	HDPE	PN16	497
80	uPVC	PN10	3,849
80	uPVC	PN16	1,793
100	uPVC	PN10	7,615
100	uPVC	PN16	455
150	uPVC	PN10	4,926
150	uPVC	PN16	679
200	uPVC	PN10	3,626
200	uPVC	PN16	1,039
250	uPVC	PN10	1,405
300	uPVC	PN10	326
400	DCI	PN10	873
		Total Length	**27,081**

Appendix D

Pipe Inventory of Alemgena subsystem

Diameter (mm)	Material	Pipe Class	Total Length (m)
50	HDPE	PN10	3,353
80	uPVC	PN10	4,366
80	uPVC	PN16	392
100	uPVC	PN10	8,446
100	uPVC	PN16	1,583
150	uPVC	PN10	9,321
200	uPVC	PN10	5,031
250	uPVC	PN10	1,518
300	uPVC	PN10	732
350	DCI	PN10	584
400	DCI	PN10	1,285
450	DCI	PN10	355
500	DCI	PN10	1,865
		Total Length	**38,827**

Appendix E

Pipe Inventory for Walate subsystem

Diameter (mm)	Material	Pipe Class	Total Length (m)
50	uPVC	PN16	
80	uPVC	PN10	333
80	uPVC	PN16	1,268
100	uPVC	PN10	3,775
100	uPVC	PN16	2,512
150	uPVC	PN10	1,494
150	uPVC	PN16	701
200	uPVC	PN10	665
250	uPVC	PN10	1,228
300	uPVC	PN10	268
		Total Length	**12,242**

Appendix F

Demand pattern

Time Period	Multiplier
00_01	0.3
01_02	0.3
02_03	0.3
03_04	0.3
04_05	0.3
05_06	0.7
06_07	1.1
07_08	1.9
08_09	1.7
09_10	1.5
10_11	1.5
11_12	1.4
12_13	1.4
13_14	1.3
14_15	1.2
15_16	1.5
16_17	1.6
17_18	1.5
18_19	1.3
19_20	1
20_21	0.7
21_22	0.5
22_23	0.4
23_24	0.3
Total	**24**

Appendix G

Pressure at peak flow

Node ID	Pressure (m H2O)
Al_J123	45.571
Al_J5	39.683
Al_J132	57.944
Al_J65	40.345
Al_J183	55.023
Al_J2	-1.751
Al_04_3	5.929
Al_J217	-4.422
Al_J174	56.615
Al_J85	28.847
Al_J141	59.779
Al_J122	43.734
Al_J210	16.148
Al_03_3	-13.47
Al_J135	60.614
Al_J83	23.945
Al_04_10	49.776
Al_J13	25.722
Al_J257	-4.055
Al_04_6	59.894
Al_J21	7.071
Al_J39	27.06
Al_J41	17.983
Al_J207	18.735
Al_J109	50.791
Al_J185	58.216
Al_J58	37.874
Al_J64	40.335
Al_J10	27.724
Al_J147	52.644
Al_J124	54.2
Al_J127	52.841
Al_J129	52.652
Al_04_1	57.613
Al_J178	43.492

Al_J24	14.664
Al_J3	15.192
Al_J211	15.074
Al_J218	-0.555
Al_J171	60.954
Al_J241	3.644
Al_J112	55.187
Al_J49	29.008
Al_J256	-0.645
Al_J89	47.307
Al_J200	29.726
Al_J208	19.048
Al_J104	54.019
Al_J189	56.891
Al_J93	33.709
Al_J197	43.531
Al_J56	29.654
Al_J182	56.597
Al_J162	45.849
Al_04_8	-1.063
Al_J130	55.561
Al_J28	42.974
Al_J95	35.338
Al_J164	40.805
Al_J51	48.357
Al_J170	58.252
Al_01_1	-15.027
Al_J53	47.291
Al_J238	-2.138
Al_J230	29.496
Al_J90	39.023
Al_J32	32.453
Al_J216	-3.048
Al_J225	25.454
Al_J68	45.066
Al_J258	0.296
Al_J146	51
Al_J42	3.654

Al_J176	60.52
Al_J142	59.227
Al_J167	32.776
Al_J204	17.011
Al_J138	55.191
Al_J214	3.228
Al_J154	29.763
Al_J62	40.525
Al_J37	31.395
Al_J73	30.165
Al_02_3	37.849
Al_J231	28.012
Al_J66	45.133
Al_J57	36.63
Al_J25	28.087
Al_J169	51.361
Al_J179	50.475
Al_J163	45.057
Al_J54	36.967
Al_J44	16.665
Al_J155	28.051
Al_J148	40.577
Al_J61	43.096
Al_J205	16.794
Al_J96	36.397
Al_J72	36.174
Al_J215	-0.487
Al_J237	1.768
Al_J232	18.802
Al_J190	58.135
Al_J159	50.106
Al_J172	57.613
Al_J99	35.544
Al_J234	15.284
Al_J50	37.091
Al_J6	20.341
Al_J43	13.684
Al_J20	7.615

Al_J145	38.959
Al_04_9	34.836
Al_J187	57.289
Al_J139	56.82
Al_J194	57.036
Al_J36	33.37
Al_J106	53.918
Al_J4	34.738
Al_J35	41.212
Al_J128	52.795
Al_J55	25.641
Al_J100	37.218
Al_J137	55.466
Al_J165	33.639
Al_J71	39.972
Al_J94	35.782
Al_J48	27.706
Al_J196	50.141
Al_J160	50.332
Al_J136	57.706
Al_J255	1.55
Al_J219	8.689
Al_J59	40.42
Al_J77	-7.674
Al_J108	50.866
Al_02_7	53.663
Al_J235	7.285
Al_J191	52.476
Al_J213	7.091
Al_J84	21.272
Al_J156	26.179
Al_J209	17.585
Al_J81	31.436
Al_J46	26.521
Al_J119	52.778
Al_J26	45.365
Al_J233	18.479
Al_J9	28.215

Al_02_4	17.13
Al_J74	19.257
Al_J227	23.732
Al_J193	58.363
Al_J259	15.008
Al_J87	53.109
Al_04_5	39.803
Al_J158	48.589
Al_J229	27.564
Al_J88	51.953
Al_J113	55.434
Al_J14	24.789
Al_J33	39.818
Al_J221	4.836
Al_01_2	26.503
Al_J105	54.647
Al_J82	28.719
Al_J226	24.336
Al_J12	14.656
Al_J168	43.158
Al_J40	23.279
Al_J45	22.391
Al_J203	24.053
Al_J29	38.947
Al_J114	54.378
Al_J220	6.983
Al_J125	54.413
Al_J118	53.351
Al_J184	56.454
Al_J111	55.525
Al_J15	10.572
Al_J19	22.456
Al_J80	15.706
Al_J199	35.133
Al_J107	53.61
Al_J76	-5.035
Al_J150	32.201
Al_J131	59.574

Al_J120	52.145
Al_J30	34.235
Al_04_2	52.283
Al_04_7	39.117
Al_J180	57.125
Al_02_2	48.989
Al_J101	41.226
Al_J236	5.532
Al_J201	28.763
Al_J181	59.073
Al_04_4	16.389
Al_J186	54.53
Al_J8	32.563
Al_J126	53.954
Al_J34	42.268
Al_J151	33.001
Al_03_2	-3.452
Al_J110	51.071
Al_J202	24.331
Al_J70	40.469
Al_J18	29.593
Al_02_1	45.879
Al_02_5	31.492
Al_J195	54.498
Al_J31	32.163
Al_J91	36.247
Al_J60	42.358
Al_J16	23.487
Al_J11	21.565
Al_J79	8.44
Al_J102	47.892
Al_J121	48.625
Al_J166	29.601
Al_J212	11.665
Al_J242	-2.303
Al_J206	18.324
Al_J161	47.334
Al_03_1	2.983

Al_J47	28.657
Al_J222	-1.818
Al_J7	19.73
Al_J78	-5.069
Al_J67	44.938
Al_J260	25.235
Al_02_6	17.133
Wa_J6	75.704
Wa_J44	51.525
Wa_J75	61.967
Wa_J46	87.279
Wa_03_6	13.872
Wa_03_11	9.961
Wa_J53	48.759
Wa_J40	68.665
Wa_02_1	40.688
Wa_03_1	41.555
Wa_J14	43.826
Wa_J12	109.7
Wa_J33	42.177
Wa_J59	65.565
Wa_J5	66.959
Wa_J81	57.601
Wa_J30	9.652
Wa_J65	88.57
Wa_J8	82.901
Wa_J61	77.813
Wa_J58	67.512
Wa_J34	66.975
Wa_J21	81.139
Wa_03_2	62.485
Wa_03_8	44.233
Wa_J4	46.312
Wa_J10	102.655
Wa_J66	91.477
Wa_J71	72.37
Wa_03_5	89.307
Wa_J52	40.961

Wa_J25	23.097
Wa_03_7	65.876
Wa_J35	71.311
Wa_J29	13.443
Wa_J7	79.405
Wa_J67	83.239
Wa_J48	5.862
Wa_J22	88.328
Wa_J84	11.764
Wa_J24	50.148
Wa_J3	40.66
Wa_J39	95.704
Wa_03_9	81.366
Wa_03_10	59.433
Wa_J19	87.414
Wa_J11	107.868
Wa_03_4	93.828
Wa_J16	37.547
Wa_J26	16.085
Wa_J72	52.409
Wa_J73	55.285
Wa_J79	93.134
Wa_J82	49.366
Wa_J50	15.584
Wa_J9	89.75
Wa_J77	89.447
Wa_J80	79.066
Wa_J38	93.999
Wa_J55	58.411
Wa_J54	47.39
Wa_J27	20.527
Wa_J41	52.573
Wa_J69	73.823
Wa_J64	82.882
Wa_J45	71.303
Wa_J70	73.406
Wa_J17	77.716
Wa_03_3	78.369

Wa_J78	92.386
Wa_J36	76.477
Wa_J83	29.343
Wa_J51	21.943
Wa_J13	72.703
Wa_J18	101.089
Wa_03_12	5.126
Wa_J60	77.934
Wa_J2	45.244
Wa_J49	8.631
Se_01_3	24.308
Se_J9	99.059
Se_J133	-2.084
Se_J64	83.458
Se_J63	66.902
Se_J127	9.89
Se_J182	57.286
Se_J156	25.338
Se_J110	22.5
Se_J152	9.047
Se_J124	27.424
Se_J52	-7.193
Se_J130	3
Se_J170	13.646
Se_J31	81.146
Se_J179	78.054
Se_J74	79.164
Se_J136	-11.299
Se_02_1	91.422
Se_J21	68.815
Se_J13	74.567
Se_J85	83.381
Se_J48	23.288
Se_J134	-7.283
Se_J59	33.645
Se_01_5	98.993
Se_J95	68.589
Se_J166	43.993

Se_J30	81.399
Se_J71	27.421
Se_02_3	2.615
Se_J109	16.051
Se_J23	64.514
Se_01_Enyi	101.084
Se_J84	83.388
Se_J157	11.852
Se_J158	3.113
Se_J89	117.074
Se_J19	53.714
Se_J138	-24.397
Se_J101	29.029
Se_J169	21.191
Se_J61	34.892
Se_J65	61.265
Se_J6	97.268
Se_J145	-20.837
Se_J45	31.947
Se_J129	9.614
Se_J60	32.854
Se_J73	64.777
Se_J150	-6.841
Se_J117	55.532
Se_J69	17.408
Se_J155	23.404
Se_J16	59.187
Se_J66	49.501
Se_J144	-38.737
Se_J58	46.063
Se_01_2	53.408
Se_J108	14.249
Se_J53	-8.373
Se_J11	91.698
Se_J116	52.444
Se_J68	19.319
Se_J165	38.529
Se_J111	22.783

Se_J37	69.432
Se_J35	65.38
Se_J121	64
Se_J46	24.953
Se_J49	17.672
Se_J10	96.126
Se_J94	73.528
Se_J139	-30.498
Se_02_4	3.344
Se_J81	93.396
Se_J40	69.348
Se_J8	99.744
Se_J47	27.878
Se_J3	48.927
Se_J181	52.385
Se_J113	34.788
Se_J34	67.524
Se_J168	36.771
Se_J177	68.406
Se_J123	29.392
Se_J67	46.977
Se_J159	-4.98
Se_J27	72.814
Se_J41	64.292
Se_J153	8.342
Se_J172	10.397
Se_J175	41.484
Se_J164	39.386
Se_J167	35.257
Se_J5	88.332
Se_J25	70.437
Se_J141	-43.751
Se_01_1	70.323
Se_J77	92.677
Se_J29	81.81
Se_J103	74.844
Se_J76	90.493
Se_J149	-13.132

Se_J137	-11.866
Se_J151	9.488
Se_J115	43.619
Se_J28	80.664
Se_J78	99.007
Se_J163	54.286
Se_J107	14.034
Se_J42	51.945
Se_J148	-13.62
Se_J143	-50.147
Se_J176	50.607
Se_J183	55.583
Se_J4	70.435
Se_J50	13.09
Se_02_5	-43.65
Se_J44	35.106
Se_J140	-31.355
Se_J132	-10.674
Se_J97	72.011
Se_J147	-15.718
Se_J2	79.932
Se_02_2	12.62
Se_J26	71.268
Se_J75	86.792
Se_J105	25.681
Se_J171	12.124
Se_J154	15.282
Se_J43	35.229
Se_J96	67.175
Se_J91	92.514
Se_J39	68.857
Se_J18	57.407
Se_J100	67.469
Se_J80	92.267
Se_J131	-7.54
Se_J70	24.793
Se_J98	78.743
Se_J57	26.15

Se_J36	69.054
Se_J160	-3.8
Se_J86	81.633
Se_J33	84.478
Se_J24	67.417
Se_J104	61.507
Se_01_4	96.009
Se_J99	80.757
Se_J120	57.115
Se_J38	68.895
Se_J125	31.638
Se_J106	16.915
Se_J122	41.245
Se_J114	40.744
Se_J142	-46.688
Se_J92	83.077
Se_J135	-12.422
Se_J54	-9.731
Se_J15	61.729
Se_J146	-20.322
Se_J88	107.871
Se_J14	66.595
Se_J7	97.006
Se_05_1	82.792
Se_J119	58.664
Se_J118	56.655
Se_J17	57.404
Se_J83	89.93
Se_02_6	-8.489
Di_J136	16.041
Di_J159	22.118
Di_J3	1.895
Di_J177	49.842
Di_J92	82.043
Di_J11	74.184
Di_J182	48.112
Di_J18	92.065
Di_J14	88.409

Di_J65	-26.555
Di_J190	65.238
Di_J111	22.567
Di_05_2	11.701
Di_J66	-36.381
Di_J84	19.054
Di_J152	48.857
Di_J140	-13.926
Di_J20	92.961
Di_J60	30.846
Di_J83	17.846
Di_J172	27.331
Di_J43	88.977
Di_J88	-6.485
Di_J7	38.701
Di_J194	17.008
Di_01_6	44.43
Di_J189	72.421
Di_J74	-7.707
Di_J224	95.557
Di_J216	106.132
Di_J79	6.899
Di_J58	55.27
Di_J69	-5.059
Di_J8	49.344
Di_J171	27.97
Di_J219	103.443
Di_J174	15.343
Di_J9	56.662
Di_J19	92.634
Di_J118	35.948
Di_J196	22.482
Di_J184	64.991
Di_05_3	93.865
Di_J124	69.933
Di_J25	100.403
Di_J59	41.623
Di_J56	55.047

Di_J146	-2.038
Di_01_7	1.077
Di_J220	105.982
Di_J181	46.996
Di_J89	-10.222
Di_J114	25.342
Di_J87	-0.977
Di_J37	86.657
Di_J40	82.283
Di_05_1	93.222
Di_J201	61.374
Di_J198	18.672
Di_J23	98.42
Di_J179	46.871
Di_J144	-3.403
Di_J115	28.572
Di_J64	-15.593
Di_J29	92.035
Di_J49	80.541
Di_J117	31.04
Di_J116	31.321
Di_J12	80.384
Di_J113	22.945
Di_J99	61.908
Di_J4	0.479
Di_J142	-7.86
Di_J86	8.667
Di_J96	66.075
Di_J166	50.664
Di_J73	-6.448
Di_J213	104.524
Di_J154	40.858
Di_J55	59.149
Di_J39	85.396
Di_J108	21.905
Di_J36	85.924
Di_J68	-6.312
Di_J135	35.489

Di_05_4	62.134
Di_J75	-9.774
Di_J169	32.534
Di_J15	87.564
Di_J54	65.933
Di_J151	51.214
Di_J203	65.903
Di_J222	98.812
Di_J155	36.499
Di_J61	18.781
Di_J72	-2.092
Di_J149	50.319
Di_J33	88.372
Di_J150	50.827
Di_J100	44.502
Di_J24	99.149
Di_01_4	28.199
Di_J217	106.071
Di_01_1	75.828
Di_J160	17.136
Di_J223	96.492
Di_J210	102.385
Di_J98	59.678
Di_J126	80.467
Di_J200	21.992
Di_J27	97.292
Di_J211	107.295
Di_J207	39.87
Di_J110	33.435
Di_J101	36.192
Di_J168	41.598
Di_J129	63.846
Di_J71	-3.22
Di_J121	58.641
Di_J133	52.767
Di_J10	67.643
Di_J202	65.777
Di_01_8	-12.688

Di_J52	72.795
Di_J77	-40.193
Di_J34	87.889
Di_J78	-11.907
Di_J153	45.864
Di_J47	90.827
Di_J145	-2.575
Di_J143	2.207
Di_J32	87.7
Di_J191	55.653
Di_J162	8.775
Di_J41	84.144
Di_J93	82.285
Di_J173	19.294
Di_J214	105.108
Di_J125	75.411
Di_J94	74.774
Di_J120	44.496
Di_J31	92.061
Di_J82	19.542
Di_J28	99.561
Di_J157	27.404
Di_J109	31.705
Di_J62	6.766
Di_01_9	-22.575
Di_J2	11.85
Di_J185	71.997
Di_J131	59.834
Di_J48	86.676
Di_J35	87.911
Di_J17	91.201
Di_J212	106.143
Di_J45	93.431
Di_J97	60.509
Di_J26	98.234
Di_J42	89.864
Di_J38	84.389
Di_J112	19.267

Di_J123	67.069
Di_J16	89.368
Di_J63	-0.455
Di_J138	-5.623
Di_J183	59.232
Di_J221	105.87
Di_J161	13.248
Di_J70	-4.636
Di_J178	45.04
Di_J218	105.998
Di_J105	8.691
Di_01_5	19.002
Di_J156	34.414
Di_J30	91.66
Di_J21	93.547
Di_01_2	53.136
Di_J46	90.315
Di_J205	50.422
Di_J225	94.894
Di_01_3	48.398
Di_J53	74.746
Di_J206	49.296
Di_J195	21.883
Di_J50	82.875
Di_J197	21.127
Di_J85	13.797
Di_02_1/1	-42.369
Di_J95	73.137
Di_J6	28.312
Di_J132	56.52
Di_J1	5.749
Di_J139	-8.542
Di_J215	104.974
Di_J204	61.153
Di_J199	19.956
Di_J119	39.867
Di_J102	25.675
Di_J22	99.302

Di_J76	-10.371
Di_J13	85.74
Di_J180	45.862
Di_J130	59.566
Di_J167	42.195
Di_J44	93.735
Di_J188	74.326
Di_J175	19.081
Se_J90	107.054
Di_J231	-6.487
Di_J232	-17.372
Di_J228	-7.765
Di_J230	-0.511
Di_J229	-2.107
Di_02_1/2	-22.807
Al_J175	56.407

Appendix H

Pressure at low flow

Node ID	Pressure (m)
Al_J123	73.239
Al_J5	55.988
Al_J132	76.718
Al_J65	65.638
Al_J183	70.208
Al_J2	19.448
Al_04_3	20.927
Al_J217	9.568
Al_J174	72.02
Al_J85	60.228
Al_J141	71.231
Al_J122	71.287
Al_J210	36.276
Al_03_3	5.295
Al_J135	76.98
Al_J83	56.523
Al_04_10	80.066
Al_J13	30.301
Al_J257	9.816
Al_04_6	76.894
Al_J21	7.176
Al_J39	34.813
Al_J41	27.048
Al_J207	40.506
Al_J109	79.719
Al_J185	75.163
Al_J58	56.904
Al_J64	64.763
Al_J10	35.509
Al_J147	60.001
Al_J124	80.649
Al_J127	78.672
Al_J129	76.196
Al_04_1	70.926
Al_J178	50.791
Al_J24	15.013

Al_J3	34.232
Al_J211	34.927
Al_J218	14.085
Al_J171	74.437
Al_J241	16.885
Al_J112	84.713
Al_J49	40.931
Al_J256	14.012
Al_J89	77.048
Al_J200	52.37
Al_J208	40.468
Al_J104	80.901
Al_J189	78.44
Al_J93	63.379
Al_J197	64.489
Al_J56	46.841
Al_J182	71.448
Al_J162	54.207
Al_04_8	35.997
Al_J130	77.515
Al_J28	44.828
Al_J95	65.966
Al_J164	49.916
Al_J51	61.183
Al_J170	70.595
Al_01_1	7.259
Al_J53	61.546
Al_J238	11.317
Al_J230	41.367
Al_J90	68.483
Al_J32	36.769
Al_J216	10.48
Al_J225	35.843
Al_J68	72.642
Al_J258	13.865
Al_J146	59.765
Al_J42	13.499
Al_J176	77.034

Al_J142	71.619
Al_J167	42.896
Al_J204	40.758
Al_J138	69.421
Al_J214	17.675
Al_J154	35.221
Al_J62	63.877
Al_J37	38.036
Al_J73	62.648
Al_02_3	44.973
Al_J231	40.029
Al_J66	71.417
Al_J57	54.589
Al_J25	28.679
Al_J169	62.632
Al_J179	59.207
Al_J163	53.722
Al_J54	52.148
Al_J44	27.547
Al_J155	34.135
Al_J148	46.526
Al_J61	65.911
Al_J205	40.167
Al_J96	67.503
Al_J72	67.453
Al_J215	13.397
Al_J237	15.022
Al_J232	31.247
Al_J190	80.992
Al_J159	57.677
Al_J172	71.756
Al_J99	64.232
Al_J234	28.217
Al_J50	49.465
Al_J6	34.753
Al_J43	24.061
Al_J20	8.138
Al_J145	49.133

Al_04_9	63.666
Al_J187	75.998
Al_J139	70.338
Al_J194	76.471
Al_J36	39.546
Al_J106	81.771
Al_J4	52.559
Al_J35	46.923
Al_J128	77.93
Al_J55	41.748
Al_J100	65.631
Al_J137	70.004
Al_J165	43.196
Al_J71	70.189
Al_J94	65.931
Al_J48	39.422
Al_J196	70.452
Al_J160	58.104
Al_J136	73.361
Al_J255	16.936
Al_J219	24.219
Al_J59	60.23
Al_J77	28.47
Al_J108	79.689
Al_02_7	66.753
Al_J235	20.318
Al_J191	77.236
Al_J213	22.949
Al_J84	53.275
Al_J156	32.887
Al_J209	38.119
Al_J81	65.157
Al_J46	37.998
Al_J119	79.621
Al_J26	46.199
Al_J233	31.209
Al_J9	37.905
Al_02_4	27.874

Al_J74	53.622
Al_J227	34.9
Al_J193	77.623
Al_J259	27.489
Al_J87	83.244
Al_04_5	61.423
Al_J158	56.053
Al_J229	39.078
Al_J88	81.974
Al_J113	85.013
Al_J14	28.603
Al_J33	44.6
Al_J221	21.466
Al_01_2	32.467
Al_J105	82.014
Al_J82	61.892
Al_J226	35.115
Al_J12	19.728
Al_J168	53.77
Al_J40	31.688
Al_J45	33.586
Al_J203	47.456
Al_J29	41.313
Al_J114	84.172
Al_J220	22.893
Al_J125	80.802
Al_J118	79.996
Al_J184	72.328
Al_J111	84.834
Al_J15	14.041
Al_J19	23.485
Al_J80	49.962
Al_J199	57.283
Al_J107	81.948
Al_J76	31.703
Al_J150	37.11
Al_J131	79.938
Al_J120	79.244

Al_J30	37.384
Al_04_2	63.647
Al_04_7	63.165
Al_J180	67.289
Al_02_2	49.984
Al_J101	69.167
Al_J236	18.597
Al_J201	51.711
Al_J181	70.248
Al_04_4	40.181
Al_J186	72.503
Al_J8	44.324
Al_J126	80.016
Al_J34	47.515
Al_J151	37.415
Al_03_2	10.674
Al_J110	80.119
Al_J202	47.695
Al_J70	69.625
Al_J18	31.127
Al_02_1	47.933
Al_02_5	36.679
Al_J195	74.348
Al_J31	35.96
Al_J91	65.426
Al_J60	63.24
Al_J16	26.283
Al_J11	27.396
Al_J79	43.233
Al_J102	75.087
Al_J121	75.951
Al_J166	39.568
Al_J212	30.273
Al_J242	11.703
Al_J206	40.48
Al_J161	55.552
Al_03_1	19.025
Al_J47	40.24

Al_J222	15.634
Al_J7	33.006
Al_J78	30.391
Al_J67	72.149
Al_J260	36.629
Al_02_6	25.628
Wa_J6	102.677
Wa_J44	53.799
Wa_J75	75.461
Wa_J46	90.422
Wa_03_6	15.175
Wa_03_11	33.664
Wa_J53	54.232
Wa_J40	72.786
Wa_02_1	75.26
Wa_03_1	55.247
Wa_J14	58.945
Wa_J12	129.032
Wa_J33	44.619
Wa_J59	73.722
Wa_J5	95.523
Wa_J81	77.645
Wa_J30	10.506
Wa_J65	102.108
Wa_J8	106.429
Wa_J61	90.198
Wa_J58	74.551
Wa_J34	70.555
Wa_J21	88.82
Wa_03_2	71.729
Wa_03_8	49.785
Wa_J4	76.554
Wa_J10	123.086
Wa_J66	105.439
Wa_J71	81.847
Wa_03_5	92.918
Wa_J52	46.676
Wa_J25	25.517

Wa_03_7	70.196
Wa_J35	75.377
Wa_J29	14.382
Wa_J7	104.612
Wa_J67	97.852
Wa_J48	15.208
Wa_J22	94.54
Wa_J84	35.214
Wa_J24	53.275
Wa_J3	72.581
Wa_J39	100.823
Wa_03_9	93.997
Wa_03_10	72.688
Wa_J19	97.35
Wa_J11	127.863
Wa_03_4	99.115
Wa_J16	50.401
Wa_J26	18.277
Wa_J72	63.993
Wa_J73	67.58
Wa_J79	110.231
Wa_J82	70.071
Wa_J50	23.107
Wa_J9	111.599
Wa_J77	105.308
Wa_J80	97.419
Wa_J38	98.87
Wa_J55	62.993
Wa_J54	52.434
Wa_J27	22.334
Wa_J41	56.014
Wa_J69	82.45
Wa_J64	95.842
Wa_J45	73.943
Wa_J70	82.69
Wa_J17	89.513
Wa_03_3	82.379
Wa_J78	108.802

Wa_J36	80.2
Wa_J83	51.439
Wa_J51	28.949
Wa_J13	89.501
Wa_J18	111.86
Wa_03_12	15.828
Wa_J60	89.566
Wa_J2	78.843
Wa_J49	16.87
Se_01_3	38.34
Se_J9	110.162
Se_J133	19.865
Se_J64	93.572
Se_J63	77.313
Se_J127	28.744
Se_J182	60.585
Se_J156	56.037
Se_J110	40.787
Se_J152	32.582
Se_J124	44.425
Se_J52	16.996
Se_J130	23.066
Se_J170	14.155
Se_J31	85.391
Se_J179	81.823
Se_J74	85.301
Se_J136	22.957
Se_02_1	103.625
Se_J21	74.792
Se_J13	84.251
Se_J85	88.082
Se_J48	45.287
Se_J134	19.172
Se_J59	46.376
Se_01_5	109.976
Se_J95	84.302
Se_J166	46.591
Se_J30	85.567

Se_J71	34.696
Se_02_3	21.756
Se_J109	33.776
Se_J23	69.346
Se_01_Enyi	109.101
Se_J84	88.219
Se_J157	44.601
Se_J158	34.793
Se_J89	126.979
Se_J19	60.411
Se_J138	17.357
Se_J101	47.727
Se_J169	21.947
Se_J61	45.915
Se_J65	71.74
Se_J6	109.979
Se_J145	20.809
Se_J45	48.807
Se_J129	29.232
Se_J60	44.986
Se_J73	70.573
Se_J150	21.254
Se_J117	68.677
Se_J69	25.202
Se_J155	52.051
Se_J16	67.406
Se_J66	59.291
Se_J144	5.618
Se_J58	59.876
Se_01_2	56.872
Se_J108	31.585
Se_J53	15.933
Se_J11	102.162
Se_J116	65.729
Se_J68	27.843
Se_J165	41.636
Se_J111	41.204
Se_J37	79.718

Se_J35	73.908
Se_J121	79.187
Se_J46	43.526
Se_J49	40.406
Se_J10	106.846
Se_J94	88.687
Se_J139	15.313
Se_02_4	37.206
Se_J81	101.23
Se_J40	80.66
Se_J8	111.723
Se_J47	48.164
Se_J3	64.423
Se_J181	55.538
Se_J113	48.567
Se_J34	75.425
Se_J168	37.783
Se_J177	71.327
Se_J123	46.02
Se_J67	56.03
Se_J159	20.797
Se_J27	77.209
Se_J41	76.787
Se_J153	32.888
Se_J172	10.736
Se_J175	42.876
Se_J164	42.921
Se_J167	37.009
Se_J5	102.066
Se_J25	74.977
Se_J141	9.06
Se_01_1	76.505
Se_J77	99.999
Se_J29	85.993
Se_J103	89.879
Se_J76	97.355
Se_J149	17.674
Se_J137	26.133

Se_J151	34.873
Se_J115	57.151
Se_J28	84.914
Se_J78	106.788
Se_J163	58.727
Se_J107	31.195
Se_J42	65.38
Se_J148	19.895
Se_J143	-3.604
Se_J176	52.578
Se_J183	58.998
Se_J4	85.045
Se_J50	36.227
Se_02_5	9.356
Se_J44	51.012
Se_J140	18.512
Se_J132	10.657
Se_J97	88.814
Se_J147	20.507
Se_J2	96.883
Se_02_2	31.649
Se_J26	75.741
Se_J75	93.207
Se_J105	41.717
Se_J171	12.567
Se_J154	41.201
Se_J43	50.78
Se_J96	83.197
Se_J91	104.514
Se_J39	79.815
Se_J18	64.625
Se_J100	85.533
Se_J80	100.218
Se_J131	13.212
Se_J70	32.113
Se_J98	96.079
Se_J57	41.002
Se_J36	78.119

Se_J160	19.544
Se_J86	85.941
Se_J33	91.002
Se_J24	72.166
Se_J104	76.98
Se_01_4	103.72
Se_J99	98.412
Se_J120	71.476
Se_J38	79.658
Se_J125	49.412
Se_J106	33.616
Se_J122	57.152
Se_J114	54.368
Se_J142	3.385
Se_J92	96.908
Se_J135	17.933
Se_J54	14.746
Se_J15	70.042
Se_J146	18.614
Se_J88	116.726
Se_J14	75.456
Se_J7	109.351
Se_05_1	101.209
Se_J119	72.586
Se_J118	69.942
Se_J17	65.265
Se_J83	96.205
Se_02_6	16.758
Di_J136	28.749
Di_J159	41.51
Di_J3	4.217
Di_J177	61.242
Di_J92	87.55
Di_J11	79.123
Di_J182	64.395
Di_J18	99.677
Di_J14	94.634
Di_J65	7.923

Di_J190	85.113
Di_J111	24.701
Di_05_2	14.023
Di_J66	-1.294
Di_J84	43.132
Di_J152	71.303
Di_J140	2.771
Di_J20	101.373
Di_J60	61.119
Di_J83	42.371
Di_J172	49.086
Di_J43	103.925
Di_J88	15.694
Di_J7	41.933
Di_J194	18.899
Di_01_6	54.558
Di_J189	91.49
Di_J74	21.588
Di_J224	107.044
Di_J216	116.275
Di_J79	32.426
Di_J58	83.586
Di_J69	27.511
Di_J8	53.032
Di_J171	48.629
Di_J219	114.162
Di_J174	39.141
Di_J9	60.626
Di_J19	100.924
Di_J118	40.596
Di_J196	23.538
Di_J184	82.306
Di_05_3	109.704
Di_J124	79.295
Di_J25	109.802
Di_J59	70.911
Di_J56	81.203
Di_J146	19.473

Di_01_7	14.873
Di_J220	116.893
Di_J181	62.956
Di_J89	12.758
Di_J114	29
Di_J87	21.736
Di_J37	99.242
Di_J40	95.349
Di_05_1	101.568
Di_J201	62.65
Di_J198	19.173
Di_J23	107.268
Di_J179	60.258
Di_J144	16.658
Di_J115	32.382
Di_J64	18.278
Di_J29	102.964
Di_J49	98.012
Di_J117	35.346
Di_J116	35.283
Di_J12	85.893
Di_J113	26.147
Di_J99	63.166
Di_J4	2.8
Di_J142	10.607
Di_J86	31.974
Di_J96	69.091
Di_J166	67.374
Di_J73	23.38
Di_J213	114.077
Di_J154	62.226
Di_J55	83.729
Di_J39	98.271
Di_J108	22.195
Di_J36	98.363
Di_J68	27.007
Di_J135	47.041
Di_05_4	68.859

Di_J75	18.683
Di_J169	51.332
Di_J15	93.916
Di_J54	88.986
Di_J151	73.954
Di_J203	67.588
Di_J222	109.915
Di_J155	57.273
Di_J61	50.046
Di_J72	28.421
Di_J149	76.238
Di_J33	100.465
Di_J150	75.157
Di_J100	45.387
Di_J24	108.148
Di_01_4	47.571
Di_J217	116.406
Di_01_1	94.128
Di_J160	36.561
Di_J223	107.787
Di_J210	111.569
Di_J98	61.448
Di_J126	92.224
Di_J200	22.339
Di_J27	107.362
Di_J211	116.554
Di_J207	43.193
Di_J110	34.888
Di_J101	36.919
Di_J168	59.7
Di_J129	71.159
Di_J71	28.056
Di_J121	64.764
Di_J133	62.596
Di_J10	72.241
Di_J202	67.18
Di_01_8	5.187
Di_J52	92.971

Di_J77	-13.014
Di_J34	100.039
Di_J78	14.496
Di_J153	67.826
Di_J47	107.439
Di_J145	18.252
Di_J143	21.728
Di_J32	99.704
Di_J191	76.742
Di_J162	28.264
Di_J41	97.691
Di_J93	87.169
Di_J173	41.994
Di_J214	114.867
Di_J125	85.912
Di_J94	79.035
Di_J120	50.013
Di_J31	103.883
Di_J82	44.146
Di_J28	109.941
Di_J157	46.99
Di_J109	32.575
Di_J62	39.01
Di_01_9	1.806
Di_J2	14.172
Di_J185	89.706
Di_J131	68.328
Di_J48	103.737
Di_J35	100.23
Di_J17	98.336
Di_J212	115.518
Di_J45	109.355
Di_J97	62.902
Di_J26	108.133
Di_J42	104.111
Di_J38	97.119
Di_J112	22.16
Di_J123	75.059

Di_J16	96.027
Di_J63	32.48
Di_J138	9.161
Di_J183	76.228
Di_J221	116.853
Di_J161	32.696
Di_J70	27.249
Di_J178	57.726
Di_J218	116.525
Di_J105	8.832
Di_01_5	43.938
Di_J156	54.594
Di_J30	103.001
Di_J21	102.104
Di_01_2	80.168
Di_J46	106.479
Di_J205	52.926
Di_J225	106.572
Di_01_3	64.526
Di_J53	96.875
Di_J206	52.209
Di_J195	23.356
Di_J50	100.603
Di_J197	21.765
Di_J85	37.449
Di_02_1/1	-6.675
Di_J95	76.775
Di_J6	31.089
Di_J132	65.604
Di_J1	8.071
Di_J139	7.199
Di_J215	114.925
Di_J204	63.248
Di_J199	20.356
Di_J119	44.715
Di_J102	26.229
Di_J22	108.005
Di_J76	17.401

Di_J13	91.704
Di_J180	61.119
Di_J130	67.47
Di_J167	59.6
Di_J44	109.547
Di_J188	92.703
Di_J175	43.963
Se_J90	118.278
Di_J231	17.188
Di_J232	6.789
Di_J228	14.574
Di_J230	22.931
Di_J229	20.848
Di_02_1/2	1.962
Al_J175	72.376

Appendix I

1. Calibration for Computed and Measured pressure value during peak demand time

Measured pressure	Computed pressure
25.124	45.571
1.012	5.929
11.301	25.722
21.028	32.776
38.214	59.574
55.574	109.7
32.01	46.312
1.254	5.862
7.018	16.085
9.125	20.527
65.178	117.074
1.011	3.344
51.265	68.406
21.521	35.257
7.985	14.034
45.23	61.374
22.214	32.534
83.25	107.295
3.85	8.775
12.245	19.267

2. Calibration for Computed and Measured pressure value during low demand time

Measured pressure	Computed pressure
43.259	73.239
7.021	20.927
10.254	30.301
28.252	42.896
54.125	79.938
81.101	129.032
50.241	76.554
7.017	15.208
8.201	18.277
13.253	22.334
76.205	126.979
26.96	37.206
56.321	71.327
26.281	37.009
18.201	31.195
47.261	62.65
37.871	51.332
85.018	116.554
15.241	28.264
12.258	22.16

Appendix J

1. Correlated values during pressure calibration for peak demand time

Measured Pressure	Computed pressure
38.245	65.225
2.521	25.112
22.253	45.332
29.124	52.215
57.021	79.214
102.214	135.259
41.254	76.256
3.256	20.123
13.102	26.215
17.321	35.321

110.259	127.357
1.981	13.205
65.417	78.356
31.263	40.126
12.014	16.051
58.502	61.374
29.105	35.128
100.011	101.224
5.254	35.194
17.368	40.928

2. Correlated values during pressure calibration for low demand time

Measured pressure	Computed pressure
64.125	90.129
16.021	40.123
27.365	30.301
37.254	62.851
72.205	95.205
123.051	149.101
72.365	96.665
13.204	35.625
14.058	28.987
17.014	42.129
118.369	140.259
35.251	57.009
67.046	91.451
35.014	51.187
29.011	51.524
58.359	62.65
48.148	51.332
111.051	116.554
25.012	28.264
18.258	22.16

Appendix K

Picture 1: During coordinates and elevation data collection on site by using Hand GPS 60**.**

Picture 2: Hand GPS 60 used to collect coordinates and elevation data

Appendix L

Picture 3: During the time of elevation data collection on site by using leveling.

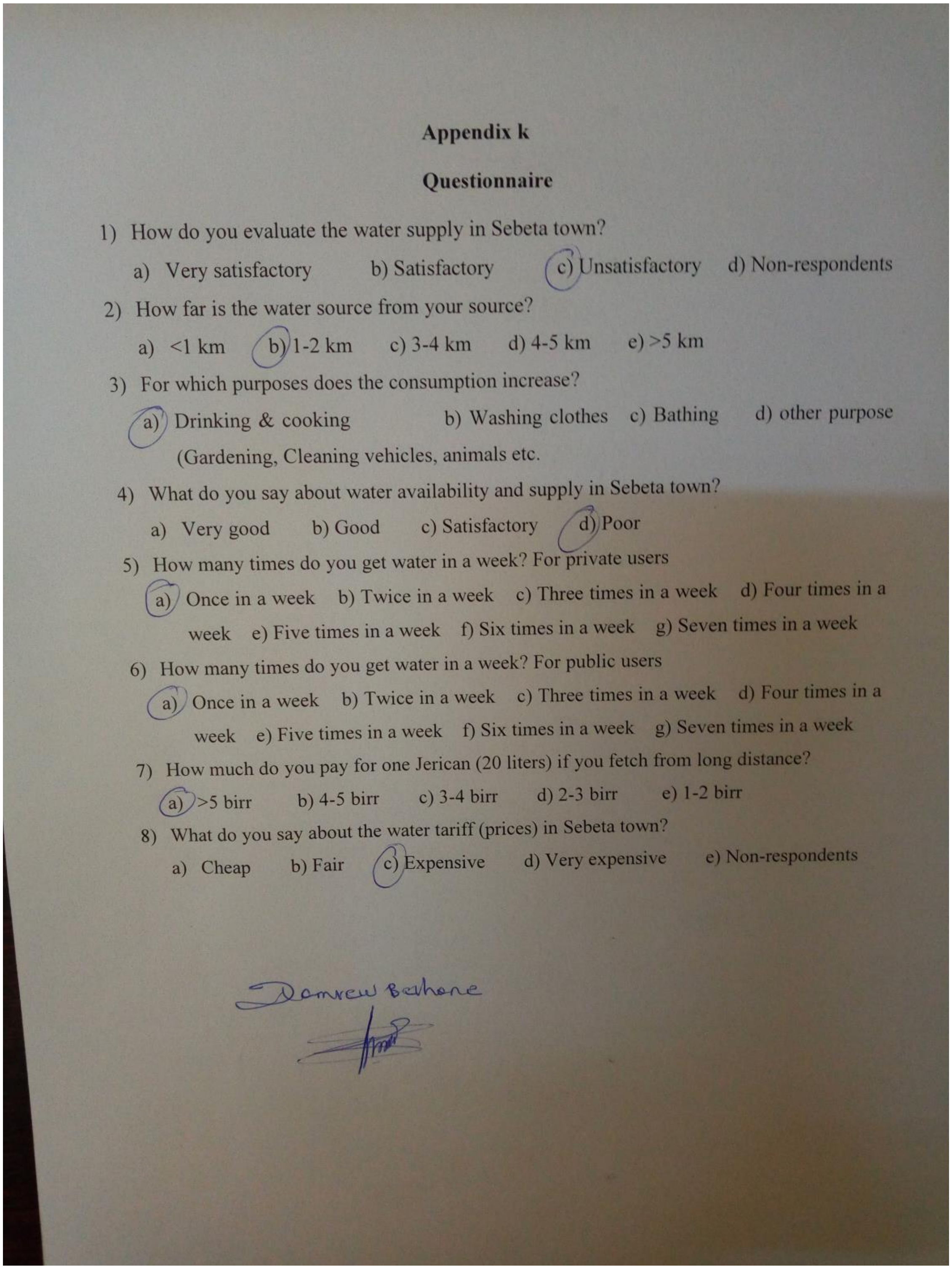
Appendix M

Questionnaire

1) How do you evaluate the water supply in Sebeta town?
   a) Very satisfactory b) Satisfactory c) Unsatisfactory d) Non-respondents
2) How far is the water source from your source?
   a) <1 km b) 1-2 km c) 3-4 km d) 4-5 km e) >5 km
3) For which purposes does the consumption increase?
   a) Drinking & cooking b) Washing clothes c) Bathing d) other purpose (Gardening, Cleaning vehicles, animals etc.
4) What do you say about water availability and supply in Sebeta town?
   a) Very good b) Good c) Satisfactory d) Poor
5) How many times do you get water in a week? For private users
   a) Once in a week b) Twice in a week c) Three times in a week d) Four times in a week e) Five times in a week f) Six times in a week g) Seven times in a week
6) How many times do you get water in a week? For public users
   a) Once in a week b) Twice in a week c) Three times in a week d) Four times in a week e) Five times in a week f) Six times in a week g) Seven times in a week
7) How much do you pay for one Jerican (20 liters) if you fetch from long distance?
   a) >5 birr b) 4-5 birr c) 3-4 birr d) 2-3 birr e) 1-2 birr
8) What do you say about the water tariff (prices) in Sebeta town?
   a) Cheap b) Fair c) Expensive d) Very expensive e) Non-respondents

Appendix N

The respondent's answer for questionnaire on the answer sheet with the name and signature



Appendix k

Questionnaire

1) How do you evaluate the water supply in Sebeta town?
   a) Very satisfactory b) Satisfactory c) Unsatisfactory d) Non-respondents
2) How far is the water source from your source?
   a) <1 km b) 1-2 km c) 3-4 km d) 4-5 km e) >5 km
3) For which purposes does the consumption increase?
   a) Drinking & cooking b) Washing clothes c) Bathing d) other purpose (Gardening, Cleaning vehicles, animals etc.
4) What do you say about water availability and supply in Sebeta town?
   a) Very good b) Good c) Satisfactory d) Poor
5) How many times do you get water in a week? For private users
   a) Once in a week b) Twice in a week c) Three times in a week d) Four times in a week e) Five times in a week f) Six times in a week g) Seven times in a week
6) How many times do you get water in a week? For public users
   a) Once in a week b) Twice in a week c) Three times in a week d) Four times in a week e) Five times in a week f) Six times in a week g) Seven times in a week
7) How much do you pay for one Jerican (20 liters) if you fetch from long distance?
   a) >5 birr b) 4-5 birr c) 3-4 birr d) 2-3 birr e) 1-2 birr
8) What do you say about the water tariff (prices) in Sebeta town?
   a) Cheap b) Fair c) Expensive d) Very expensive e) Non-respondents

Demrew Berhane

Appendix O

Picture 4: During measuring pressure on site by using pressure log (metro log).

Appendix P

Picture 5: During pressure measurement

Appendix Q

Picture 6: Instruments and reagent used for water quality laboratory test

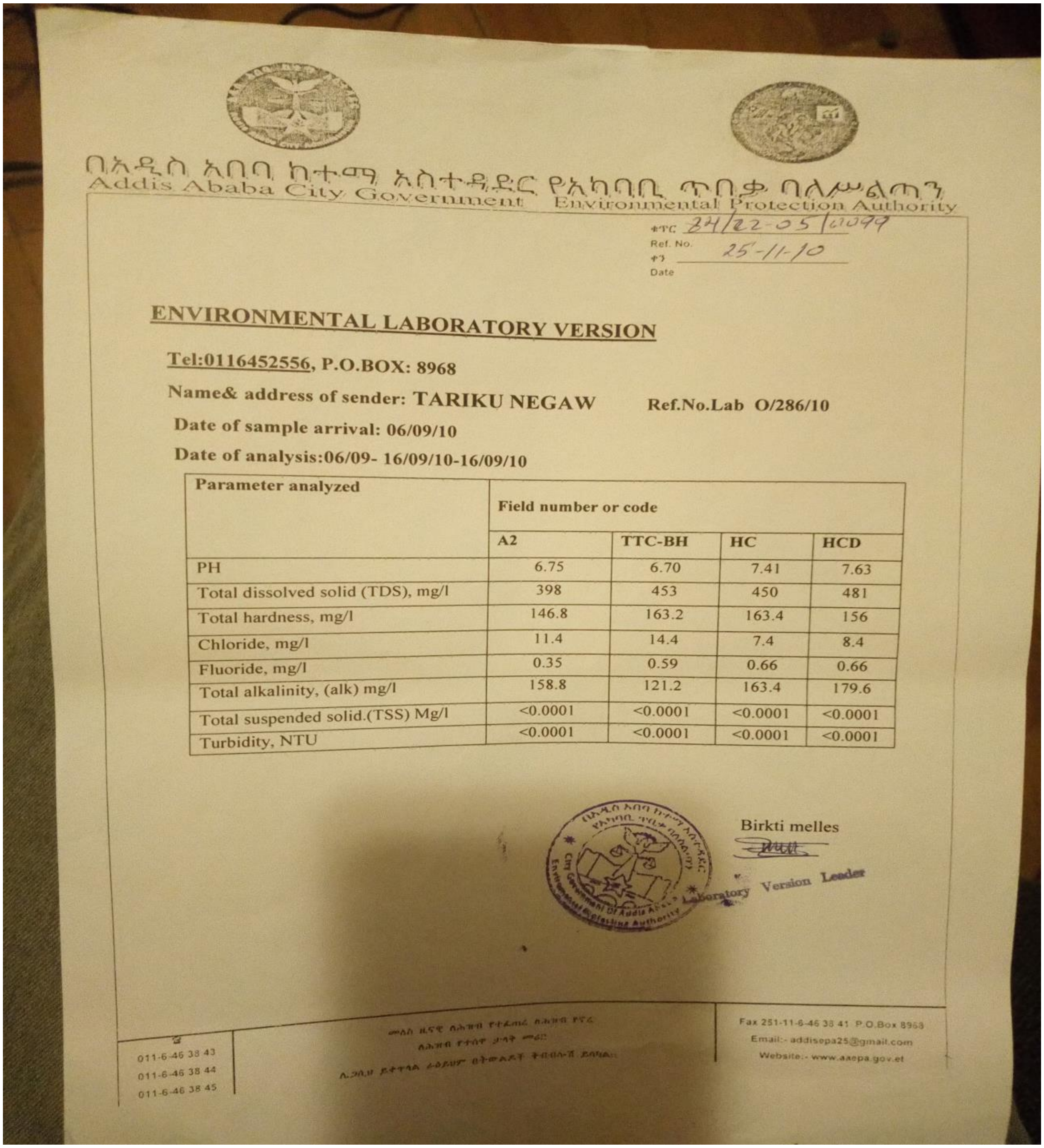
Picture 7: Instruments and reagent used for water quality laboratory test

Appendix R

Picture 8: During working on water quality by using laboratory test

Appendix S

Table 1: Samples, Parameters and water quality laboratory test results



በአዲስ አበባ ከተማ አስተዳደር የአካባቢ ጥበቃ ባለሥልጣን
Addis Ababa City Government Environmental Protection Authority

Ref. No. 34/22-05/0099
Date 25-11-10

ENVIRONMENTAL LABORATORY VERSION

Tel:0116452556, P.O.BOX: 8968

Name& address of sender: TARIKU NEGAW **Ref.No.Lab O/286/10**

Date of sample arrival: 06/09/10

Date of analysis:06/09- 16/09/10-16/09/10

Parameter analyzed	Field number or code			
	A2	TTC-BH	HC	HCD
PH	6.75	6.70	7.41	7.63
Total dissolved solid (TDS), mg/l	398	453	450	481
Total hardness, mg/l	146.8	163.2	163.4	156
Chloride, mg/l	11.4	14.4	7.4	8.4
Fluoride, mg/l	0.35	0.59	0.66	0.66
Total alkalinity, (alk) mg/l	158.8	121.2	163.4	179.6
Total suspended solid.(TSS) Mg/l	<0.0001	<0.0001	<0.0001	<0.0001
Turbidity, NTU	<0.0001	<0.0001	<0.0001	<0.0001

Birkti melles
Laboratory Version Leader

011-6-46 38 43
011-6-46 38 44
011-6-46 38 45

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